Utilization of waste plastic bottles strips as fiber reinforcement for soil stabilization of landfill plots in new housing societies

By

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Project Supervisor: Engr. Prof. Dr. Majid Ali

BS CIVIL ENGINEERING

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DEPARTMENT OF CIVIL ENGINEERING
CAPITAL UNIVERSITY OF SCIENCE & TECHNOLOGY
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CERTIFICATE OF APPROVAL

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CERTIFICATE

This is to verify that **Mr. Attique Ur Rehman** and **Mr. Waleed Abdullah** have integrated all comments, suggestions and observations made by the evaluator as well as the internal evaluator and project supervisor. Their project title is **“Utilization of waste plastic bottles strips as fiber reinforcement for soil stabilization of landfill plots in new housing societies”.**

Forwarded for necessary action.

Engr. Prof. Dr. Majid Ali
(Project Supervisor)

Date: July, 2023

DEDICATION

This effort is devoted to our respected and cherishing **Parents**, who helped us through each troublesome of our life and yielded every one of the comforts of their lives for our brilliant future. This is likewise a tribute to our **Honorable teachers** who guided us to go up against the troubles of presence with ingenuity and boldness, and who made us what we are today.

Attique Ur Rehman	(BCE193107)
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DECLARATION

This report is a presentation of our assigned project work. Wherever commitments of others are included, each exertion is made to demonstrate this obviously, with due reference to the writing, and affirmation of communitarian project and exchanges. The work is carried out under the supervision of Engr. Prof. Dr. Majid Ali, at the Capital University of Science and Technology, Islamabad, Pakistan.

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Date: July, 2023

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LIST OF ABBREVIATIONS AND SYMBOLS

AASHTO	American Association of Soil for Highway and Transportation
BS	British Standard
c	Cohesion
CBR	California Bearing Ratio
DEA	Department of Environment Affairs
EC	European Commission
HDPE	High density Polyethylene
LDPE	Low density Polyethylene
OMC	Optimum Moisture Content
OPC	Ordinary Portland Cement
P	Pressure
PET	Polyethylene Terephthalate
PP	Polypropylene
PS	Polystyrene
PVC	Polyvinyl Chloride
t	Time
UW	Unit Weight
V	Volume
W	Water Content
W	Weight
Wwet	Wet Water Content
ρ	Density

ABSTRACT

Techniques for stabilizing the soil are essential for assuring the stability and endurance of construction projects. Unconventional techniques for stabilizing soil, like as plastic bottle strips, have drawn interest recently because of their possible environmental advantages and affordability. The use of plastic bottle strips for soil stabilization in waste plots within new housing societies is the subject of this study. The use of plastic in various industries, such as government, schools, agriculture, the automotive sector, the health sector, etc., has, on the other hand, led to significant growth in the plastics industry. A difficulty with handling non-biodegradable plastics eventually develops as a result of growing plastic usage. The issues that the fields of soil waste management and civil engineering have to face are the main focus of this project. Expansive soil sample is used in this project, as well as PET waste plastic bottle strips have been used in the research at Capital University of Science and Technology.

The particle size distribution (sieve analysis), Atterberg's limits, unconfined compressive (UCS), compaction, and direct shear testing are a few of the experiments conducted that are used to attain the purpose of this final year research. Analyzing the outcomes of testing soil samples treated with plastic bottle strips is necessary for evaluating lab reports for potential soil stabilization utilizing these strips. which also Obtain the lab results, analyze the plastic bottle strip preparation, evaluate the compaction characteristics, assess the shear strength, analyze the permeability, and take other pertinent tests into consideration. Compare outcomes to requirements and standards, take into account real-world factors, and offer recommendations. The soil's characteristics were tested in the study on unreinforced clayey soil to examine how rising percentages of plastic waste bottle strips would impact them. The clayey soil was reinforced with waste plastic bottle strips in varying amounts, including 2%, 4%, and 8% used by weight.

The project's findings provide engineers and construction professionals with essential information on soil stabilization that use plastic bottle strips. The results of soil stabilization using plastic bottle strips can vary depending on a number of variables, including the properties of the soil, the method used for preparation, the method used for installation, and the environment. The following are some possible effects of utilizing plastic bottle strips to stabilize soil: improved compaction, enhanced shear strength, decreased permeability, and increased load-bearing capacity.

CHAPTER 1: INTRODUCTION

1.1. Background

One of the difficult soils found all over the world, expansive soil demands special treatment to control its natural tendency to expand and compress. Environmental change causes the expanding soil to regularly swell and compress. Depending on the level of moisture, the soil either expands when wet or reduces when dry. The volumetric instability of the expanding soil is mostly due to the clay mineral "montmorillonite". Buildings on these soils additionally produce uplift forces but also stop the soil's natural volume change. These manufactured plastics are often thrown away in the waste. The low rate of disintegration of plastic materials such Plastic Polyethylene Terephthalate (PET) bottles causes significant problems for recycling as post-consumer waste made of plastic is becoming more and more commonplace. The total amount of bottled water consumed globally climbed to 391 billion liters in 2016 from 288 billion liters in 2012 (Koohmishi and Palassi, 2022).

Plastics bottles takes almost 200 to 500 years to decompose. Despite the fact that plastic has an extensive number of practical uses, we have grown dependent on single-use plastics, which has negative effects on the environment, society, the economy, and our health. Around the globe, one million bottles of plastic are purchased each minute, and five trillion bags of plastic are consumed each year. One use only is the intended application for half of all plastic produced, which means it will be thrown after use. Plastics, specifically microplastics, are widely used nowadays. As they accumulate in the historical record of the earth, they serve as a symbol of what is known as the Anthropocene, the epoch we are presently living in. They even named the "plastisphere," a novel setting for bacteria that live under the sea. Researchers are attempting to raise the caliber of geotechnical components in response to social, economic, and environmental difficulties (Sahoo and Singh, 2022). Research has shown that adding fiber plastic materials, such as PET plastic waste, to low quality soil greatly improves function and longevity. This method has, however, been criticized in the field of civil engineering.

1.2. Project motivation and problem statement

For many years, local soils that are easily accessible have been improved by adding additions like lime, cement, and cement kiln dust. Evaluations of laboratory and field performance show that adding these chemicals may reinforce and stabilize such soils. But just lately, the cost of using such substances has also increased. Producing and introducing different types of soil additives, such as plastics, bamboo, liquid enzyme soil stabilizers, and others, has become significantly easier as a result. Because soil qualities vary significantly and because the development of structures is heavily dependent on the soil's carrying ability, stabilizing the soil is required to make it simpler to anticipate and even raise the soil's load bearing capacity. It's important to take the gradation of the soil into consideration when working with it. The soils may be uniformly graded, which appears stable but actually has more voids, or well-graded, which is more desirable since it has less voids. To improve the strength attributes of landfills for new housing societies, soil stabilization is necessary. As a result, the issue with the statement is as follows:

In order to safeguard the natural resources by making use of the waste in a useful way, it is vital to determine the proper number and quantity of waste plastic bottle strips for the stability of soil. This research will help determine the right quantity and type of additive in order to stabilize vast soils for a new housing society. In expansive soil, correct load distribution is a problem that this stabilized soil will assist to address, but utilizing conventional additives to stabilize the soil is not cost-effective and is not environmentally safe.

1.2.1. Project questions

- Whether soil properties can be enhanced using PET plastic strips of landfill area?
- Why we were using PET plastic rather than other?
- Is it a suitable material for road construction?
- What are its applications in Civil Engineering?
- Is expensive soil-PET plastic strips combination sustainable?

1.3. The overall project program goals and the specific objectives of this BS design project

The main goal of this project program is to propose a better method for improving soil characteristics by adding PET plastic bottle strips to landfill plots of new housing societies while keeping in mind that it should be cost-effective and waste management should be done properly.

The specific aims of this BS project are:

1. Contrasting the mechanical characteristics of soil that has regularly been treated with admixture with untreated soil.

2. Examining in laboratories the mechanical characteristics of soil improved with PET plastic waste. Sieve analysis, compaction, direct shear, unconfined compressive, and Atterberg's limits are a few examples of laboratory tests.

3. To suggest applications for soil having waste PET-type plastic strips in geotechnical engineering and applications.

1.4. Study limitation and scope of work

Limitation of this research is the soil collected from UET Taxila, Punjab and percentage of PET plastic bottles strips used in the research. This study looked at the engineering behavior of soil with the PET plastic bottles strips in landfill areas.

The following topics were covered by the study's purview: Only strips from plastic bottles may be used as an ingredient in this project. There will be about 38 samples created in total. The various laboratory tests (Sieve analysis test, compaction test, UCS test, Atterberg’s limit, direct shear testing) were conducted to verify the composite of soil and pet sample.

1.4.1. Rationale behind the variable’s selections

The main argument for the decision is to decrease pollutants and improve soil qualities. The goal of the research is to enhance the site's features, make the soil load-bearing, and raise the shear strength by making the soil less compressible. The combination of plastic bottle strips and pricey soil is suggested to alleviate the problem of disposing of waste from combustion and to lower project costs. The main reason of soil stabilization of only landfill area is because the population increases gradually day by day and cities are expending due to over population. So, it is a major concern to develop the expending area of cities and the first process of development is make a flat land which requires cut and fill.

1.5. Brief methodology

In order to perform this investigation, a variety of materials including pricey soil (disturbed and undisturbed samples) were obtained from UET Taxila, Punjab, and plastic bottle strips were purchased from Plastic Industry I-9, Islamabad. The PET bottle strips are used in varying percentages (2%, 4%, 8% etc.). The sample was subsequently put through to various experiments, including the particle distribution test, the unconfined test, the Atterberg's limit test, the direct shear test, and the compaction test, both in the lab and on the field.

1.6. Project uniqueness, project significance, and practical implementation

Making soil (landfill soil or new housing society) more stable is the major goal of this BS project in the larger setting of housing societies. Given the lack of adequate soil quality for embankments and fills, utilizing plastic bottle strips as a soil stabilizer therefore represents an effective and financially viable use. By creating valuable materials from non-useful waste, this project attempts to address society's difficulties by reducing the amount of plastic garbage produced, which will lay the groundwork for a sustainable society. Ground improvement has benefited significantly from the usage of plastic garbage. The qualities of the soil used to build road infrastructure can be significantly enhanced. The end result is a better, more durable road with a higher load carrying capacity.

The research study's findings will add to the data and literature on reinforcement of soil with PET plastic waste. Additionally, addressing the issues that civil engineering and management of waste industries encounter, in order to examine the importance of this study, a cost comparison was made for the preparation of the soil of a new housing society with and In order to determine whether utilizing plastic bottle strips to stabilize soil is economically feasible and advantageous, it is important to evaluate the costs of various stabilization techniques. For this purpose, a large area of new housing societies designed over a period of 35-40 years was considered as per the AASHTO design. Waste management will benefit from a decrease in PET plastic waste, which typically gets disposed of in landfills if it is not properly gathered and recycled and, as a result, obstructs water flow, causing drainage to block.

The field of engineering for civil purposes would benefit from the improvement of the functionality and performance of low-quality soil that may be used in the construction of buildings, slopes, embankments, retaining walls, and other civil engineering structures. Before building structures that are more complicated, the soil must be stabilized. Many building contractors include soil stabilization services in their plans when constructing new highways, overpasses, parking lots, and even airports. The pavement may become increasingly fragile as the soil swells, creating cracks and bumps that could potentially be dangerous. Any obvious deterioration to a road can quickly cause an accident. On a runway, the consequences can be even more terrible, hazardous, and expensive. A few examples of common uses include the building of walkways, roads, highways, routes, parks, sports fields, industrial estates, industrial facilities, airfields, dams, backfilling, and landfills.

1.7. Layout of the report

This final year project is divided into four chapters, each of which includes references. Their main points are briefly outlined below:

Chapter 1 The first section discusses the broader background of soil reinforced with PET plastic waste. The section will summarize existing information on the issue and identifies any gaps in knowledge. In addition, it provides an overview of the context, issue statement, research objectives and questions, and objectives of the study, as well as its limitations and importance.

Chapter 2 An analysis of the literature on soil reinforcement using PET plastic waste is provided in the second chapter. It also displays theoretical and experimental methods developed by various researchers.

Chapter 3 This chapter presents the chosen research strategies and the plan for the research project. We provide the findings of typical tests. used to describe research materials. This chapter also describes various methods used to carry out this research.

Chapter 4 The findings of the experimental investigation on soil stabilization using plastic bottle strips are presented in chapter 4. The purpose of this chapter is to examine and interpret the laboratory testing data, with a particular emphasis on how the plastic bottle strip content affects various soil parameters and stabilization results.

Chapter 5 This chapter is about discussion chapter offers a critical analysis of the study's findings, highlighting the impact of plastic bottle strips on soil stabilization, addressing the ideal plastic content, and going over the implications for real-world use in civil engineering projects.

Chapter 6 The study's conclusions are presented in this concluding chapter based on the data, highlighting the value of plastic bottle strips for stabilizing soil and offering suggestions for their practical application, including the ideal plastic content, installation methods, and long-term monitoring.

CHAPTER 2: LITERATURE REVIEW

2.1. Background

The technique of soil stabilization results in enhanced engineering qualities and a higher level of stability. It is used to increase the soil's shear capacity while decreasing its undesirable characteristics, such as permeability and consolidation potential. Compaction and pre-consolidation procedures are routinely used to enhance soil types that are generally in good condition. However, soil stabilization goes much further than that, encouraging the usage of substandard soil and reducing the time and expense involved in replacing subpar soil. In addition to addressing the relationship of soil masses, the primary objective of this technique is to alter the soil material itself. Since 1950, 8.3 billion tons of plastic waste have been produced created, with 60% of that waste ending up in landfills or the environment. Annual waste generated by plastic manufacturing is estimated to be 9.46 million tons; 40% of this waste plastic is not collected, and 33% of it is used for packaging, mostly for single-use items (Gangwar & Tiwari, 2023).

Plastics are regarded as one of the essential inventions that have significantly contributed to various spheres of human endeavor, whether in the sciences or otherwise. Plastic has supplanted other materials, such as paper and others, that were formerly utilized for various functions, including restaurant use and residential packaging. This is because of plastic's authority capabilities. Although it has endless applications in today's society, the use of plastic and its impact on the environment have cast doubt on this material's usefulness. It has grown to be one of the leading environmental issues. In order to avoid severe circumstances that people and the environment may have to deal with in the near future, plastic consumption must already be restricted. The ability to reuse plastic and extend its useful life will significantly minimize the amount of it that is wasted. These materials have grown to such an extent that it is challenging to limit their use; instead, a replacement must be found, and actions must be done following it. Although these steps are still in progress, they have not been able to move along at the expected rate. In the world, plastic use has significantly increased, as has the amount of waste plastic produced. The process of limiting it has grown incredibly difficult (Sahoo & Singh. 2022).

2.2. Issues in landfill areas and available remedial measures

Underweight clay can experience significant settlements when it changes from being loose to rigid. Settlements of this kind will likely occur gradually since clay has poor drainage qualities. Long-term consolidating settlement is caused by the slowly moving pressures in the pore spaces inside the clay particle gaps. Different types of clay vary regionally, and each one has distinct qualities. Many locations have swelling clay (particularly throughout the prairie provinces). Depending on the moisture concentration, this clay may contract or increase. As a result, there may be subsidence or settling. With clay, particularly swelling clay, in particular, soil heave is a problem because it can cause the foundation and the building above to move upward. The primary problems with any soft-to-firm clay are the full settlements they can display under load and the rate at which they may occur. If significant area loads, such as embankment fills or area grade raise fill, are being used to load clays, thicker concentrations of soft clay might cause scheduling and settlement problems (Koohmishi and Palassi, 2022).

Built areas are being inserted further into metropolitan centers on a more frequent basis. Frequently, surviving urban sites are more challenging to develop and are omitted in favor of locations with reduced development expenses. The remaining properties are targeted for development Municipalities struggle to find room for these projects as these areas become more congested expanding people. The development of these websites frequently necessitates intensive remedial work, such as significant excavation and replacement or disposal. Fill soils come in three different varieties: hydraulically deposited fill, dumped fill and engineered fill. Of course, when filling is needed to support structures, engineered fill is frequently employed to replace non-engineered fill. It is made up of granular components or particular subgrade soils that have been thinly lifted and compacted to the lowest possible level. Engineered fill, with possibly a little constrained bearing capacity, can be relied upon to support foundations when built and monitored appropriately. By its very nature, undocumented or dumped fill is exceptionally changeable. As a result, the usual course of action is to remove it, re-engineer it into place, or, if that is not possible, replace it with approved designed fill soils (Emberton & Parker, 2017).

Following are some examples of this manual's fundamental soft ground treatment ideas.

The loads on the soft ground must be as light as is practical under the circumstances. Pick the best course of action to ensure safety or meet the execution requirements. To increase the strength through consolidation by allowing enough time for execution, an improvement approach that takes advantage of the inherent properties of the ground should take precedence in the research of the preloading method or slow loading method. Take into account the unpredictability of the inquiry, design, execution process, and constraints of the current investigation/analysis approach. Understanding the complex characteristics and distribution of the ground will help you carry out effective execution and information management.

In the case of new housing societies, many remedial measures were taken, such as using additives to enhance soil properties like plastic bottles waste, lime, lime with ash and rice husk, etc. In this study, plastic bottle strips are used as reinforcement in the soil of infilling residential areas in order to stabilize the soil.

2.2.1. Landfill areas

Settlement is carried on by empty areas in the landfill soil, fill dirt, or fill. Whatever building the foundation is sustaining will experience harm if there is uneven or excessive settling. There are many methods to overcome on this issue like providing piles, use of admixtures to stabilized the soil (plastic, lime, rice husk and fly ash etc.). In this case the soil from cut plot bring and fill it in landfill plots. The primary advantage of cutting and filling the soil to level ground surfaces is that the cut earth can potentially be recycled, negating the need to carry fill earth from a different spot and substantially lowering the cost of any ground levelling operation. Additionally, it enables constructors to reuse soil from a site by levelling the soil by cutting and filling, as compared to only filling in low areas. And some disadvantages of this are, the primary disadvantage of this method is that it produces filled, aerated, compressible regions of earth that may be unstable. If filled areas are not correctly compressed prior to anything being built on the site, they may sink and there will into depressions. Any building constructed on top of areas that subsequently decompress can experience significant damage. Furthermore, poor compaction might produce drainage issues in the filled region.

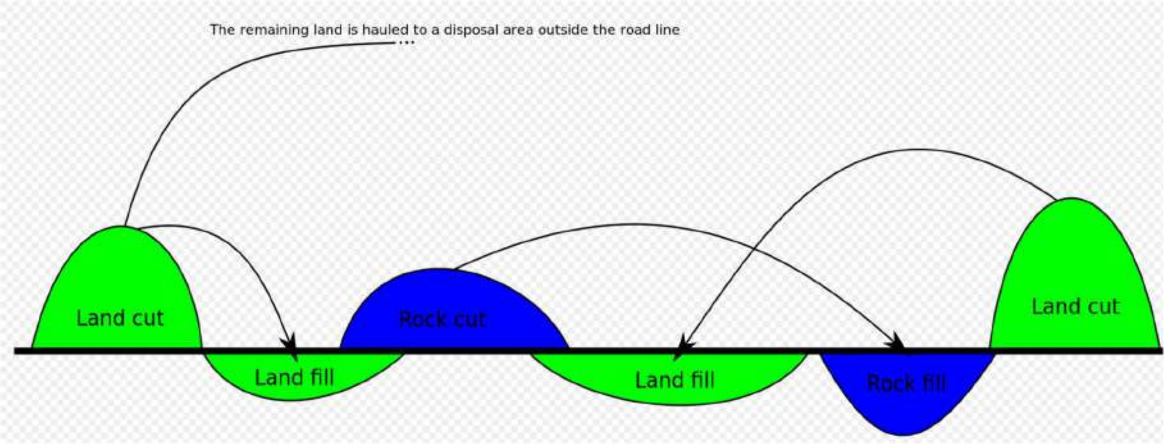


Figure 2.1 cut and fill

2.2.2. Available soil stabilization methods for landfill

The soil system is capable of changing some soil characteristics using various chemical or mechanical procedures in order to produce an improved soil material with all the necessary engineering qualities. Soils are typically maintained to make them stronger and more resilient or to halt land degradation. Because the soil's characteristics vary greatly from location to location, and in particular situations may vary from one site to another, the success of soil stabilization depends on soil testing. There are many ways to stabilize soil, but each one ought to be first evaluated in a lab using genuine soil before being applied to a field. The techniques for soil stabilization are as follows: mechanical approach of soil stabilization, The absolute cheapest approach, mechanical compression, can be used on both cohesive and cohesionless soils. The procedure includes first removing the weak soil to the mean greater, then filling or replacing it layers that have been compacted. The excavation soil can be returned in layers and compressed as necessary if it lacks cohesion or is a sand-silt clay mixture. It is not suggested to refill soil that has already been dug if it contains sandy soil, silt, or soft clay because these materials may not provide enough load carrying capacity for the foundations even when compacted. Soil quality may sometimes need to be carried in from a considerable distance (Emberton & Parker, 2017). And in additive method of soil stabilization, the proper number of manufactured products is added to the soil, enhancing the soil's physical attributes. As synthetic additions, materials like cement, lime, bitumen, fly ash, etc. are employed. Occasionally, additional fibers are added to the soil as reinforcements. With oriented fiber reinforcement, the fibers are all placed within the same direction and are organized in some sort of order. In this kind of configuration, the fibers are placed one on top of the other.

Regularly fibers in the form of sheets, strips, bars, etc. are constantly utilized in this kind of arrangement. It improves soil volume, hence improving the soil bearing capacity, The durability and workability of the soil are enhanced through stabilization and it helps to decrease the increase in soil volume. Due to inadequately compacted fill soils, we find that many of our clients have difficulties with their foundation, notably foundation settlement. Housing developments, worksites, construction projects, and landscaping efforts all make use of fill soils. We advise purchasers of new homes to search for signs of soil settlement because landfill soil: Drywall with cracks, separating kitchen countertops/cabinets from walls, Slanted flooring (a sense of vertigo) and doors and windows that stick.

2.2.3. Sustainable solutions

Due to its rigidity and durability, PET (Polyethylene Terephthalate) is effective in a variety of applications. PET may be produced into extremely durable textile fibers that can be combined with other fibers like rayon, wool, and cotton to enhance their special characteristics and avoid creases. PET can also be utilized to make fiber filler for furniture, pillows, and insulated clothing. To create synthetic silk and rugs, small and large PET filament strands are also employed. Having brick debris blended in with an expansive soil causes not a single hair cracking.

In mechanical modification process, soil is compacted using techniques in order to enhance soil characteristics such as static compacted, dynamic compacted, and deep compaction by severe tamping (Hausmann 1990, Nicholson 2014). Porewater is driven to the surface using the method known as the hydraulic modification approach by pushing it through wells or drains. For soil with a coarse grain or lack of cohesion, pumping from trench or boreholes may be used to lower the ground water. However, for perfectly fine or cohesive soils, the use of long-term external influence (preloading) or electrical equipment's (electrokinetic stabilization) is employed (Nicholson 2014). In physical and chemical modification soil stabilization with this technique involves physically incorporating chemicals with upper layers at deep. Natural soils, solid wastes or products from industry, as well as many other organic compounds that can react with the ground or soil, can all be considered additives. Other applications include thermal modifications and ground modification through grouting (Nicholson 2014, Hausmann 1990).

Incorporation and confinement method modification is thought to strengthen the soil by gradually adding like meshes, bars, strips, fibers, and fabrics with strength properties that match. Stable-earth retention structures can also be constructed by enclosing a site with steel or fabric elements (Hausmann 1990). This group includes the technique of soil stabilization, which is explained in more detail in the section that follows. In fiber reinforced soil the order to meet the demand for housing and improved infrastructure, fast urbanization and rising rural-to-city migration, along with an anticipated global population of 7 billion people, have resulted in an increase in the formation of cities. As a result, there are very few suitable places with suitable soil conditions for proposed constructions and other civil engineering works, as well as good building materials. The location of a work, such as the construction phase and any other civil engineering manufacturing effort, is important to the achievement of the project. This decides if the mission may be installed at that particular location. A site inspection is the first step in determining whether a location is suitable for any building or civil works project. This simplifies the process of determining the water and soil level houses, the site's records, and the modern conveniences available at or near to the site.

Figure 2.2 fiber reinforced soil

2.3. Management of waste plastic

The management of waste refers to all actions associated with the control of generation, storage, collection, transfer and transport, treatment and processing, and disposal of solid wastes, that comply with the best practices of public health, economics, engineering, conservation, aesthetics, and other environmental considerations (Filemon 2008; McDougall et al. 2008). The term "waste" refers to anything that is abandoned because it will not achieve the purpose it was intended for and will not be useful to or valuable to the owner (such as food, paper, or plastic). McDougall et al. (2008) claim that the following categories are used to classify waste: state (such as solid, liquid, or gaseous), origin (such as farming, mineral extraction, quarrying, industry, producing goods, building, residential, commercial, etc.), the chemical makeup of the material (combustible, able to break down and recyclable), kind of material (such as plastic, glass, metal, paper, food, etc.), and security level (such as hazardous and non-hazardous).

Numerous geotechnical infrastructure applications, such as road foundations, landfill plots, and slope stabilization, have been examined for the use of polyethylene plastic bags from waste for soil stabilization. The earth's bearing capacity, shear and tensile strength, reduced soil growth, lateral stability, increased liquefaction obstruction, and durability of weak soil can all be enhanced by mixing garbage made of plastic with the soil. Solid waste includes all garbage that isn't a gas or a liquid. The majority of the municipal garbage is composed of both residential and business solid waste (MSW). MSW is made up of a variety of substances, including glass, paper, plastic, metal, and organic waste. MSW is frequently mixed together, which makes disposal difficult to control. In order to safeguard both the environment and public health, MSW must be appropriately disposed of, which includes waste disposal, burning, and recycling. Controlling plastic waste is covered in this chapter.

2.3.1. Plastic applications

Applications for various plastic kinds include: One of the most popular thermoplastic polymeric resins, polyethylene terephthalate, is also referred to as "plastic number 1." It is popularly referred to as PETE or plastic made from PET. Plastic 2 is one of the healthier kinds of plastic. Because of its high strength-to-density ratio, it is also known as HDPE (high-density polyethylene), and it also has a tremendous resistance to wear. Not one of the best recycling codes is Plastic 3. PVC, frequently referred to as polyvinyl chloride, is one of the least recyclable substances and is quite hazardous. Although PET plastic is equally common as plastic type 3. Plastic 4, which is additionally referred to as LDPE (Low-Density Polyethylene), is one of the earliest varieties of polyethylene. LDPE 4 is regarded as having been somewhat safe to use, however only a limited amount of the plastic can be repurposed, making it not very beneficial to the environment. Plastic number 5, often known as polypropylene or PP plastic, is the second most commonly made plastic. PP is used in many types of packaging because it is strong, lightweight, and resistant to heating. The sixth plastic is polystyrene, which is additionally referred to as polystyrene (PS). Given that it is difficult to recycle six plastics, this is one of the recyclable plastic codes that should be avoided or at the very least repurposed. In essence, everything else not covered by the prior recycling of plastic regulations is referred to as Plastic 7. It consists of novel plastics, bioplastics, etc.

Table 2.1: Plastic Types and its Applications (EC 2007, Jill 2014 and SPI 2014)

Numbers	Plastic type	Applications
1	PET: Polyethylene Terephthalate	PET is a hygienic, durable, and lightweight plastic that is widely used in the packaging of food ingredients and drinks, especially comfort-sized soft drinks, juices, and water.
2	Plasticized Vinyl Chloride (PVC)	A wide range of products use PVC, including window frames, drainage and water pipe, medical equipment, blood storage bags, cable and twine insulation, durable floors, roofing membranes, stationery, automotive interiors, and seat covers.
3	Polyethylene with a high density (HDPE)	High Density Poly Ethylene, or HDPE, is a petroleum-based thermoplastic polymer. Only a handful of the packaging options for HDPE plastic include plastic bottles, milk jugs, shampoo bottles, bleach bottles, cutting forums, and pipes.
4	Polyethylene with Low Density (LDPE)	Low-Density Polyethylene (LDPE) is used most frequently in bins, meting out bottles, wash bottles, tubing, plastic bags for computer additives, and distinctive molded laboratory equipment. The most common use for low-density polyethylene is in plastic bags.

5	(PP) Polypropylene	Because of its low cost and versatility, PP has replaced conventional materials including paper, cellophane, and paper in a number of packaging types. It is used to manufacture pallets, bottles, jars, yoghurt containers, hot beverage cups, food packaging, and other goods.
6	(PS) Polystyrene	The solid, economical plastic polystyrene (PS) is used to create a variety of products, including disposable plastic cutlery and dinnerware, CD "jewel" cases, smoke detector housings, license plate frames, and plastic model assembly kits.
7	Others include Polyester and Polyimides.	Polyesters are used to create a variety of products, including bottles, films, tarps, sails (made of Dacron), canoes, liquid crystal displays, holograms, filters, dielectric film for capacitors, film insulation for cord, and insulating tapes. Many different textiles, including clothing and carpets, contain polyamide.

2.3.2. Soil stabilization using waste plastic

Plastic is used in a variety of industries, include building, manufacturing, automotive, furniture, sports, electrical & technology, health & safety, consumer goods, and household appliances. In the realm of civil engineering (AASHTO), plastic is a material that is used for building bridges, buildings, roads, highways, ports, railroads, landscaping, landfills, and water retention structures. Some of the plastic parts used in the construction industry include sound barriers, guide rails/guard rails, piles, piers, railroad ties, pallets, curbs/wheel stops, docks, board walks and sidewalks, bicycle racks, foundational backfills, erosion prevention and construction component separations were important. In order to be considered the greatest material for construction in civil engineering, something must be robust, ductile, easy to use, fire resistant, and reasonably priced.

Building plastics also offer the following qualities: they are strong and can withstand knocks and scratches; they can withstand weather extremes; they are lightweight; and they are durable. Plastics are easy to assemble and move, they can be molded into any shape and come in a wide variety of colors, opaque or transparent finishes, rigid or flexible items, they can help houses use less energy because they are poor heat exchangers and can provide a tight seal, they require less maintenance and don't need painting, and it is possible to reuse plastic building materials Plastic is a cost-effective material for building since it is long-lasting, high-quality, and requires minimal maintenance. It may additionally be converted into energy with little energy input. (Toledo and Burlingame, 2006).

2.3.3. Plastic waste management and recycling

Paper, ceramics, glass, and aluminum are a few of the materials used in substantial quantities that are recycled far more frequently than plastic. Production, distribution, usage, disposal, and sorting are only a few of the procedures involved in the recycling process. The entire process is hence regarded as being difficult. However, according to DEA it is possible to recover recyclable plastics using mechanical, chemical, or thermal methods. But before the materials made of plastic can be retrieved, sorting is necessary. Utilizing technology like the field of electromagnetics flotation, fluorescence, infrared, and spectroscopic, this is primarily performed mechanically. The first stage in the mechanical plastic recycling procedure is the physical deterioration of the material using technologies like grinding and/or shredding. waste. However, it is said that the complexity of plastic waste combinations makes recycling by mechanical means only somewhat effective; as a result, the vast majority of the plastic in the environment is burned. Nevertheless, it is clear from the study's findings that recycling is still the most popular method for recycling plastic. It is easy and quick to complete.

Fig. 2.3 examines the possibility of separate from one another, recycling, and reprocessing various plastics. This type of plastic can be sorted and processed again in excess of fifty percent of the time. However, of all the plastic types, PET has the lowest potential for recycling. Can it be assumed that PET may be better suited for uses other than recycling. In terms of energy value, polystyrene has been surpassed by polyethylene and propylene (Fig. 2.4). Therefore, recycling of the former will have more beneficial effects on energy use and management than recovery of the latter. Additionally, a study by (Hashem et al.) revealed that plastic has a calorie density of about 9000 cal/g and ash concentrations of about 2%, indicating that important energy values can be produced in specific conditions.

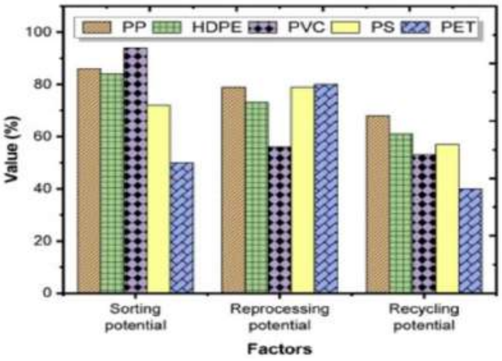


Figure 2.3 Comparison of sorting, reprocessing and recycling potentials of various plastics

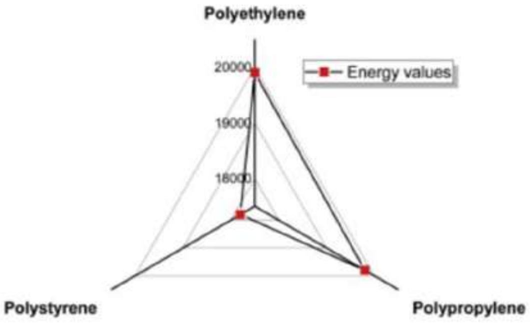


Figure 2.4 Energy values of common plastics

2.4. Summary

The finding that multiple tests have been performed on a composite made of numerous kinds of soil and plastics is reached after taking a close look at a number of research studies.

According to previous studies, the presence of plastic garbage in any form or shape will have an impact on the soil's physical characteristics, including its strength and stability. With more peace comes less soil deformation. The construction of heavy-duty roads, railways, dams, retaining walls, and tunnels may not every project benefit from a PET plastic waste fiber inclusion of 22.5%. Even However, if greater quantities of PET plastic waste are removed more than 32.5% the total amount of recyclable material that is sent to landfills will drop. Because of this, it is believed that the application of more PET plastic waste to reinforce soil will contribute to reducing the issues that the waste management and civil engineering industries are now facing.

Chapter 3: METHODOLOGY

3.1. Background

The clayey soil from UET Taxila in Islamabad was selected as the soil sample for the geotechnical soil has been investigated. a strong kind of soil that benefits from high supplements is clayey soil. Clayey soils are chilly and wet all year long and become dry inside the summer. Due to the gaps between soil particles, which make up north of 25% of these soils, earth soil types have a high water-holding capacity. When subjected to changes in their moisture content, they expand and shrink rapidly.

3.2. Collection of soil from landfill plot

The clayey soil, which was taken from UET Taxila in Punjab, Pakistan, was used as the soil sample for the geotechnical soil in this study. About 30 kg of soil sample bring from the location. The reason for choosing this site is because the soil there is clayey, and clayey soil is not recommended for construction since it is low in strength and stiffness and holds a lot of water due to the spaces between the soil particles. They expand and contract quickly when subjected to variations in moisture content. Because the foundation of any building must be built on the ground, clayey soil can present major issues for civil engineers who must ensure that the ground can support the weight of the project The engineering qualities of common soil types like MH (Mixture of Sand and Silt) or OH (Organic Clay) can be enhanced by soil stabilization procedures. These soil types have unique traits and difficulties that make stabilization necessary for construction purposes.

Figure 3.1 (a) Expansive soil and (b) Sample collection site

3.3. Preparation of PET bottles strips

And the waste plastic strips of polyethylene terephthalate (PET) that were obtained from the industry in sector I-9 of Islamabad and utilized as reinforcement material in the present investigation. The method for collecting PET bottle strip from PET bottle wastes includes arranging, cleaning, crushing, drying, and other steps. The majority of the supplied recycled PET bottle strips are utilized for staple fiber uses in the material sector. Reusing PET bottles has recently been commercially feasible due to natural factors.

3.4. Sample preparation and labelling

For the experiment, various percentages by weight of soil samples were produced using and without reinforcement from plastic from PET bottles strip waste. Both dirt and PET plastic that had been cut into pieces that averaged 0.5 mm in width and 5 mm in length were selected in advance for the experiments. The dirt had to pass through a No. 200 screen. Here are clarification of the equipment used, the substances used, the tests performed to establish the possibility that PET waste is suitable for use as a soil with clay particles stabilizer, and the methods that were used to carry out the experiment.

Table 3.1 Plastic percentage and Number of testing’s

Types of tests	Plastic Waste Content	Number of tests Proposed
Atterberg limits	0%	2
Compaction test	0%	3
	2%	3
	4%	3
	8%	3
Direct Shear test	0%	3
	2%	3
	4%	3
	8%	3
Unconfined Compressive test	0%	3
	2%	3
	4%	3
	8%	3
	Total=	38

The ASTM is an abbreviation for the American Society for Testing and Materials (ASTM), presently known as ASTM International. Technical standards have been developed and communicated by an internationally recognized organization named ASTM. for a variety of materials, goods, systems, and services. Construction, manufacturing, engineering, and testing labs are just a few of the businesses and fields that frequently use these standards, also known as ASTM standards or ASTM specifications. The quality, safety, and dependability of materials, products, and services across industries are fundamentally supported by ASTM standards. They give testing, evaluation, and specification a single reference point, encouraging innovation, trade, and public trust in the goods and materials we use every day.

3.5. Test’s procedures and parameters to be explored

In the project research, the five tests are conducted in the laboratory according to standard as indicated in table3.1 are; Atterberg's limits, the measurement of particle size distribution test, the compaction test, the direct shear test, and the unconfined compressive test.

Table 3.2 Tests, standards and parameters

Sr no.	Tests	Standard to be followed	Focus on parameter from standard
1	Particle size distribution	ASTM D6913	• The proportions of particles in a soil that are the sizes of gravel, sand, silt, and clay.
3	Atterberg limits test	ASTM D4318	• soils' plasticity index, liquid limit, and limits of plastic.
2	Compaction test	ASTM D1557	• optimal water content (wopt) and maximum dry unit weight (dmax).
4	UCS test	ASTM D2166/D 2166M-16	• shear strength, saturated and cohesive soils
5	Direct shear test	ASTM D3080-04	• Shear strength, inner angle of friction (φ'), and cohesion (c').

3.5.1. Particle size distribution test

A number of sieves with different cross section widths are used to perform the test. Each sieve has apertures that are square-shaped and a particular size. The sieve separates larger particles from more modest ones. The sieve traps grains with dimensions larger than the apertures while allowing grains with smaller widths to pass through. The soil sample is sent through the stacked sieve "tower" as part of the test, which is then followed by stacking successive sieves with logically smaller lattice sizes. As a result, the soil fragments are spread out while being captured by the numerous sieves. Additionally, the particles that make it through the final sieve are collected in a skillet. ASTM D6913 is been followed for this test, for step wise procedure check Annexure A and figure 3.3(a).

3.5.2. Compaction test

When soil particles are compacted, the amount of pore space between them is reduced. Strongly compacted soils have fewer large holes, a lower total pore volume, and a more pronounced thickness. Kneading, the mechanical stress can be generated via dynamic or static methods as well. The amount of compaction can be measured by changing the soil's dry unit weight. The beneficial effects of compaction include in particular: an improvement in permeability of the soil, a decrease in soil permeability, or the and an increase in soil strength. Following ASTM D1557 Standard Test Methods for Compaction of Soil, for further stepwise procedure check annexure A and figure 3.3(b).

3.5.3. Atterberg limits test

The following crucial moisture content values make up the Atterberg limits the Liquid Limit (LL) is the point at which a soil with fine particles no longer flows like a liquid. The Plastic Limit (PL) is the amount of moisture at which a fine-grained soil can no longer be remolded without splitting. The derived plastic range for the peat test material is hypothetical, and the estimated liquidity index values are not trustworthy indicators of its consistency, leading to the conclusion that the Atterberg limit tests are inappropriate for peat. According to ASTM D4318, soil properties like by using soil parameters like the limit of liquid content, plastic limit, and plasticity index, engineering behavior can be connected with elastic modulus, hydraulic conductivity (permeability), compatibility, shrink-swell, and shear strength., either separately or in combination.

3.5.4. Direct shear test

The direct shear test is a frequently employed laboratory test in the field of geotechnical engineering to assess the shear strength parameters of soil or other granular materials. Engineers can use the results of this test to better understand how the material responds to shear loads, which is important for a number of geotechnical applications, including slope stability studies, foundation design, and earthwork projects. Let's delve more into the justifications for using the test was performed for direct shear. The method that is used to conduct the direct shear test on soil samples under consolidated drained circumstances is described in ASTM D3080. It offers recommendations for soil samples that are both whole and remolded. A soil sample is put through the test procedure inside a shear box apparatus, which has two halves: a lower half (base) and an upper half (lid). A normal stress is imparted to the specimen by a loading mechanism after it is placed in the shear box. There are more pertinent ASTM standards for Besides ASTM D3080, the direct shear test additionally gets used. The standard test methodology for fine grain soils under undrained conditions is ASTM D6528, "Standard Test Method for Consolidated Undrained Direct Simple Shear Testing of Fine Grain Soils." for delicate clays and other fine-grained soils, it offers instructions for performing the direct shear test without allowing During the shearing procedure, drainage.

Figure 3.3 Tests to be performed: (a) Particle size distribution test, (b) Compaction test, (c) Atterberg limits test, (d) Direct shear test and (f) unconfined compressive test

3.5.5. Unconfined compressive test

Unconfined Compressive Strength (UCS) of a stone is determined using the most often used research method, the unconfined compressive test. The unconfined pressure examination method is frequently used to examine the saturated, dense soils collected from thin-walled inspection tubes. However, since dry sands or delicate soil would self-destruct in their absence of a comparable control point, the test is insufficient for these materials. Unconfined compressive strength (UCS) is the greatest axial compressive strain that a specimen can withstand in the absence of a restricting force. The unconfined compressive strength (u) of an object with a cylindrical of soil is defined as the maximum compressional force per unit of average cross-sectional surface area. The recommended testing procedure for measuring cohesive soil's compressive strength without confinement is described in ASTM D2166/D2166M-16, for further stepwise procedure check annexure A and figure 3.3(f).

3.6. Procedure for evaluating lab reports for possible soil stabilization

Evaluating the outcomes of testing soil samples treated with plastic bottle strips is necessary for the interpretation of lab reports for potential soil stabilization utilizing these strips. This process aids with assessing the potency of this novel soil stabilization method. Here is a general explanation of what happens:

Acquire the lab results: Gather the necessary lab reports that provide the testing results for the soil samples that have been subjected to the plastic bottle strips. These reports should go into depth on the testing methods used, the distinctive characteristics of the soil, and the test results. Review the soil composition analysis first: Start by looking over the soil composition analysis that was supplied in the lab reports (Malik & Sudipta, 2023). Particle size distribution, organic content, moisture content, and other pertinent soil characteristics should all be taken into account during this research. Analyze the manufacturing procedure of plastic bottle strips: Review the information given about preparing and installing the plastic bottle strips (Rahimi, et.al, 2023). This could contain information pertaining to the dimensions and properties of the plastic bottles, how they were cut and shaped into strips, and how the strips were placed in the soil.

Review the testing procedures used for assessing the efficacy of plastic bottle strips. Evaluate soil testing methods. This may entail doing research in the laboratory on treated and untreated soil samples, such as compaction testing, shear strength tests, and permeability tests. Recognize the precise testing techniques used and make sure they match accepted standards or norms (Rahimi, et.al, 2023). Analyze test outcomes: Review the lab reports' test results analysis. Compare the characteristics and behavior of the soil samples that were treated with plastic bottle strips to the samples without treatment carefully. Check for changes in permeability, shear strength, compaction characteristics, and any other pertinent soil data that point to the efficacy of the stabilizing strategy. Compare test results to relevant guidelines and specifications: Compare test findings to relevant guidelines and requirements for soil stabilization (Malik & Sudipta, 2023). These could be general geotechnical standards, precise specifications established by regulatory organizations, or project requirements. Utilizing strips from plastic bottles, determine whether the test findings satisfy the requirements for effective soil stabilization. Think about overall performance: Analyze any data offered regarding the durability and long-term effectiveness of the plastic bottle strip approach for stabilizing soil (Rahimi, et.al, 2023). Examine elements including the strips' endurance to climatic changes (such as moisture and temperature) and their susceptibility to depreciation or deterioration.

Make suggestions: Provide suggestions regarding the feasibility and efficacy of soil stabilization using plastic bottle strips based on the review of the lab data. When suggesting the potential applications and constraints of this technique, take into account the particular soil conditions, project needs, and available resources. It is crucial to remember that the use of plastic bottle strips for the evaluation of lab reports for soil stabilization is a relatively novel technique, and there isn't much data or research on how effective it is. Accurately analyzing the results can be made possible by talking to specialists in the fields of geotechnical engineering or soil stabilization.

3.7. Summary

The methodology section of the study on soil stabilization using plastic bottle strips discusses the techniques used to look into the efficacy of this novel stabilization strategy. The chapter opens with a clear statement of the research's goals, which are to determine how plastic bottle strip content affects the characteristics of soil and the effectiveness of stabilization. The procedure for gathering samples and getting them ready is thoroughly explained. The testing protocols are described, including all of the different factors that were considered in determining how well the soil stabilization strips made from plastic bottles worked. The chapter goes into further detail about the precise experimental design, which included placing plastic bottle strips inside soil samples. To ensure that standardized and uniform methods were followed, the installation technique, including the spacing and orientation of the strips, is examined.

Chapter 4: RESULTS AND ANALYSIS

4.1. Background

It was looked at how the engineering actions of the soil-PET waste plastic mixture were affected by the percentage of included PET waste plastic. This chapter presents test results, analysis, and discussions based on the multiple experiments detailed in Chapter 3. the experiments that were done on clay and clay-PET waste plastic in this chapter include sieve analysis, Atterberg's limits, compaction, unconfined compression, and direct shear testing. In both reinforced and unreinforced soil, the majority of the studies were conducted. We used plastic bottles strips as reinforcement to check the behavior with soil.

4.2. Sieve Analysis

The table 4.1 provided displays the passing percentage of PET plastic waste through different sieve sizes. Materials are sorted and separated using sieve sizes according to their particle size. The sieves in this instance contain openings of 10, 4, 7, 2, and 1/18 millimeters. The table shows that the 10mm sieve could handle all of the PET plastic garbage that was generated. This shows that no plastic garbage contained particles greater than 10 mm. About 74.53% of the PET plastic waste was able to flow through the 4.75mm sieve. This implies that a sizable proportion of the plastic waste contained particles smaller than 4.75mm, while the remainder was held on the sieve due to greater particle sizes.

Important details regarding the figure shows the size of the particles distribution of the PET plastic garbage rates via the various sieve diameters. It shows that the waste material contains particles of different sizes, with a concentration of larger particles. This knowledge is useful for waste management and recycling operations since it can be used to assess if it is feasible to use plastic waste in various applications or to choose the best techniques for size reduction and sorting.

Researchers, engineers, and waste management specialists can make well-informed choices about how to process and handle PET plastic waste by examining the passing percentages. Based on the distribution of the plastic waste's particle sizes, they can choose the best sieving or separation techniques to efficiently eliminate undesirable particles or find viable applications for it. The distribution of particle sizes curve for plastic bottle strips, with sizes ranging from 10mm to 0.6mm, is shown in Figure 4.1. This indicates that PET plastic waste is graded consistently in compliance with USCS. High-quality field materials utilized on various construction tasks in civil engineering deserve to be fairly evaluated. It was discovered that

PET waste made from plastic had both flaky and smooth particles, as shown in Figure 4.1. This made it challenging to make a precise connection when mixing it with clayey soil

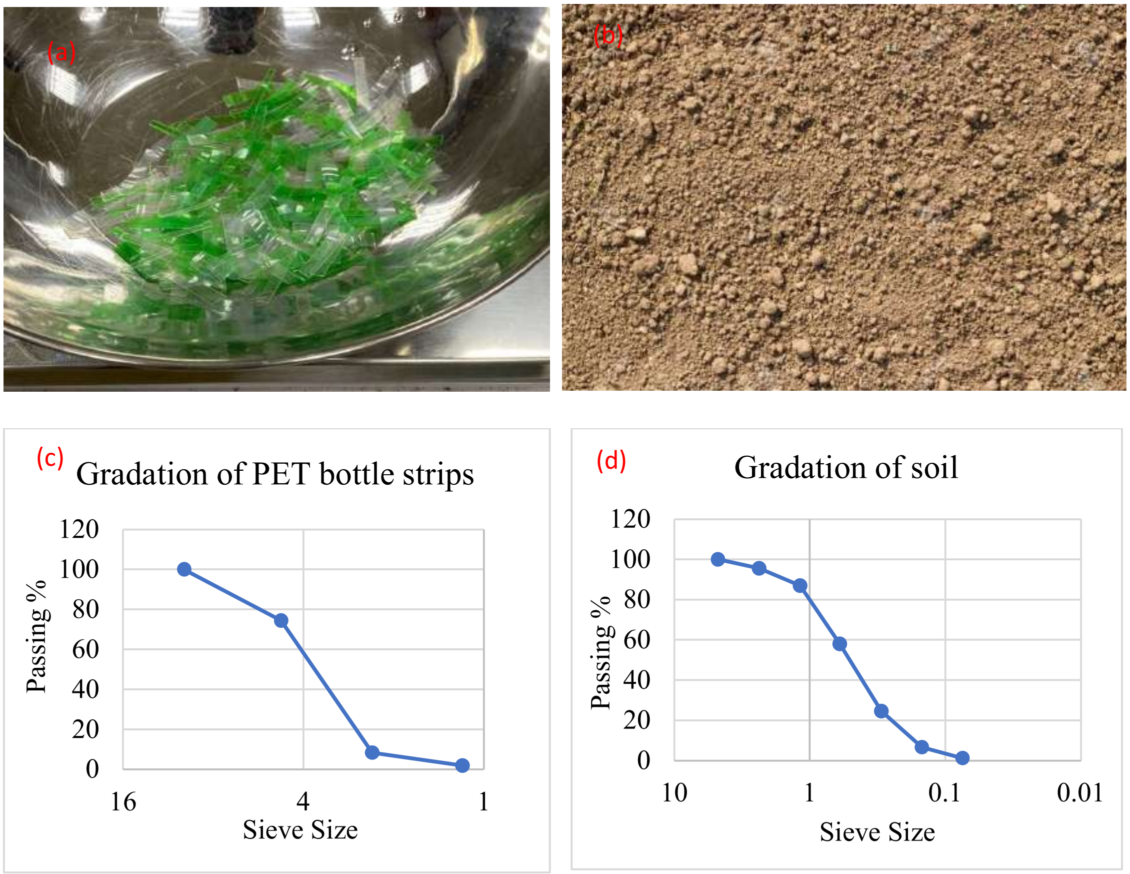


Figure 4.1. (a) Waste plastic bottles strips and (b) Expansive soil, (c) Gradation of PET bottle strips and (d) Gradation of soil

Researchers, engineers, and waste management specialists can make well-informed choices about how to process and handle PET plastic waste by examining the passing percentages. Based on the distribution of the plastic waste's particle sizes, they can choose the best sieving or separation techniques to efficiently eliminate undesirable particles or find viable applications for it. The distribution of particle sizes curve for plastic bottle strips, with sizes ranging from 10mm to 0.6mm, is shown in Figure 4.1. This indicates that PET plastic waste is graded consistently in compliance with USCS. High-quality field materials utilized on various construction tasks in civil engineering deserve to be fairly evaluated. It was discovered that PET waste made from plastic had both flaky and smooth particles, as shown in Figure 4.1. This made it challenging to make a precise connection when mixing it with clayey soils.

These numbers represent the percentage of PET plastic waste particles that can fit through each size of sieve. For instance, 100% of the particles are able to flow through the 10mm sieve when the PET plastic waste is sent through it, implying that no particles are kept on the sieve. The passing percentage declines with decreasing sieve size, suggesting that a greater percentage of particles are trapped on the sieve. For instance, only 74.53% of the particles from PET plastic waste may pass through the 4.75mm sieve, while the remaining 25.47% are held on the sieve. Similar to this, the passing percentages drop to 8.34% and 1.94%, respectively, as the sieve size is further reduced to 2.36mm and 1.18mm. This suggests that a sizeable amount of the PET plastic waste particles is held on the sieves due to their inability to flow through the smaller sieve sizes.

The weight of the soil maintained on each sieve is measured as the test progresses, and it is noted in the "Wt. of soil retained" column. The soil sample is then passed through each sieve. The "percent retained" column displays the proportion of soil retained on each sieve relative to the soil sample's starting weight. The percentage of soil that has been retained overall up to that specific sieve size is shown in the "cumulative percent retained" column. The percentage of soil particles that pass through each filter is displayed in the "percent finer" column and is computed as 100% minus the overall percent retained.

Table 4.1 (a) Sieve Analysis of PET plastic strips and (b) Sieve analysis of expensive soil

Sieve Sizes.	Passing Percentage PET plastic waste
10mm	100
4.75mm	74.53
2.36mm	8.34
1.18mm	1.94

Sieve no.#	Sieve size. mm	Sieve Wt. gm	Sieve + Soil	Wt. of soil retained	percent retained	cumulative percent retained	percent finer
4	4.75	522	522	0	0	0	100
8	2.36	490.8	505	14.2	4.526617788	4.526617788	95.47338
16	1.18	425	451.5	26.5	8.447561364	12.97417915	87.02582
30	0.6	400.8	492	91.2	29.07236213	42.04654128	57.95346
50	0.297	374.5	479	104.5	33.31208161	75.35862289	24.64138
100	0.149	354.6	411	56.4	17.97896079	93.33758368	6.662416
200	0.075	350.1	367.2	17.1	5.451067899	98.78865158	1.211348
Pan		362.2	366	3.8	1.211348422		

Let's now concentrate on the passing rate finer at a specific sieve number. Although the sieve number is not stated directly, we may determine the % finer at any given sieve size using the data. For instance, we look at the "percent finer" number corresponding to that sieve size, which is 57.95345872%, to get the passing percentage finer at the 30th sieve (0.6 mm). This indicates that 42.05% of the soil particles are kept on the sieves with smaller apertures, and 57.95% are less than or equal to 0.6 mm in size. The "percent finer" number for the 100th sieve (0.149 mm), which is 6.662416321%, is used to determine the passing percentage finer for that sieve size. According to this, just 6.66% of the soil particles have an average size of 0.149 mm or less, while the majority, or 93.34%, are captured by sieves with bigger holes. The distribution of particle sizes has a considerable impact on the soil's properties, such as permeability, compressibility, and shear strength, hence this particle size distribution test is crucial for understanding the features of the soil.

4.3. Optimum moisture content and maximum dry density

When a soil reaches its maximum compaction for a specific compactive effort, it is said to have reached OMC. It measures the amount of wetness at which soil particles can compress together most effectively, achieving the maximum density possible. OMC is frequently stated as a percentage of the soil's dry weight. The MDD is the highest bulk density that can be compressed into a soil sample. It is defined commonly as kilograms per cubic meter (kg/m3) or pounds per cubic foot (pcf), and it relates to the maximum mass of solids per unit volume of the soil. After the moisture content varies, expansive soils, sometimes referred to as shrink-swell soils, experience considerable volume changes. These soils have the potential to negatively impact construction projects since they can expand when wet and contract when dry. The soil's maximum capacity for compaction and density can be determined using the compaction test. To achieve the required amount of compaction in expansive soils, it is crucial to determine the OMC as this can assist reduce the possibility of volume fluctuations and the resulting damage.

Compaction is the process of mechanically pressing soil particles together to improve their dry weight. The benefits of this technique include increased bearing capacity, better shear strength, and increased dry density. Compacted soils have lower voids ratios, transparency, and settlements, all of which are important when analyzing the stability of earth infrastructure. In line with BS 1377: Part 4: 1990 and TMH 1: Method A7: 1986, compaction tests have been carried out for this investigation. A graph was used to establish the link between dry unit weight and content, and the highest dry density possible and ideal water content were noted. The results of tests on soil samples without the strips of plastic are shown in the table, which additionally incorporates measurements of moisture content, maximum dry density, and ideal moisture content. Additional measurements include dry unit weight, wet unit weight, mass of the empty can, mass of the can plus wet soil, mass of the can plus dry soil, and mass of water and soil solids. The highest dry density value obtained during compaction tests is 1.77565 g/cm3, which is essential for soil engineering and construction.

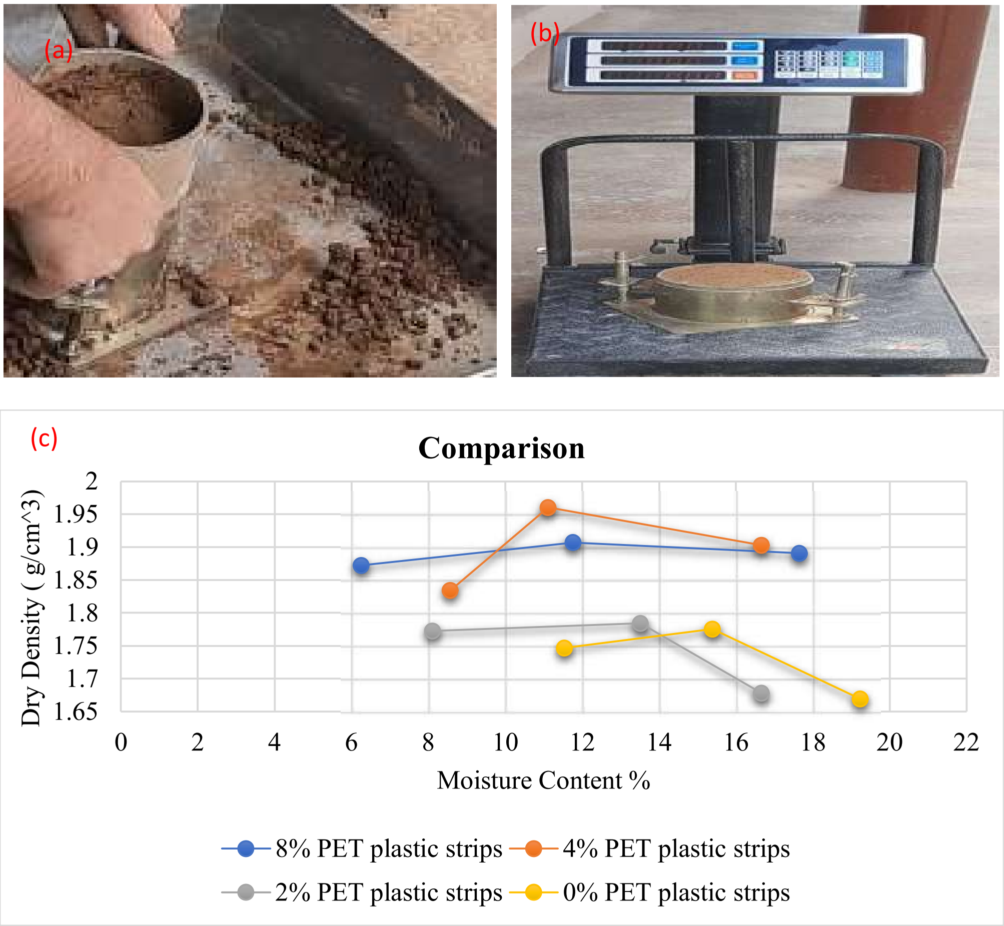


Figure 4.2. (a)Preparation of sample, (b) Compaction test and (c)Comparison of compaction test with different percentages

The table from Annexure B2 shows soil sample densities at various moisture contents, with 12% as the optimal moisture content (OMC) value. Key metrics for evaluating compaction characteristics include dry unit weight, Maximum dry density, ideal amount of moisture, wet unit weight, and moisture level. The table shows the results of tests on samples of soil that were compressed using 2% plastic strips. Wet consolidated soil, wet units, dry units, the mass of the empty can, water, soil particles, moisture content, the maximum dry density, and the ideal amount of moisture are among the variables that it includes. The dry device weights for trials

1, 2, and 3 are 1.94 g/cm3, 1.89 g/cm3, and 1.547 g/cm3, respectively. The moisture content data shows the percentage of water content in the soil samples. The highest density measured dry measurement is 1.89 g/cm3, indicating the greatest density achievable through compaction. The optimal moisture content (OMC) value is 14.35%, indicating the moisture content that produces the maximum yields.

The table 4.2 displays the results of experiments on soil samples compacted using plastic strips. It includes parameters such as mold weight, wet compacted soil, wet units, dry units, empty can mass, water, soil solids, and moisture content. The dry unit weights represent the soil's density, while the wet unit weights represent the soil's density with respect to water content. The percentage that is composed of water in the soil samples can be determined by the moisture content. The table's maximum dry density value is 1.799 g/cm3, indicating the greatest density achievable through compaction. This information is crucial in soil engineering and construction.

Table 4.2. Results of compaction test with different plastic percentages

No.	PET Plastic strips	OMC %	MDD$^{(g/cm^3)}$
1	0%	12.5	1.94
2	2%	14.35	1.89
3	4%	11.25	1.799
4	8%	13.9	1.547

The table 4.2. highest dry density value is 1.547 g/cm3, which. It stands for the highest dry unit weight that has been achieved during compaction tests. The greatest density that may be achieved through compaction is indicated by this metric, which is important in soil engineering and construction.

In this table 4.2, 14.35% is the optimal moisture content (OMC) value. It indicates the level the level of moisture that occurs when the maximum dry density is attained. The OMC is the moisture level at which the soil is most compacted (Adane & Muleta, 2023). In conclusion, the table details the soil sample densities with 8% strips of plastic added and different amounts of moisture concentrations. The moisture content, optimum moisture content and the highest possible dry density are significant factors in determining the soil's compaction characteristics and engineering features. The ideal Using plastic made from PET strips, the absolute maximum dry density (MDD) and moisture content (OMC) of expansive ground were calculated. When the soil was combined with PET plastic bottle strips and a compressive test was performed, it was evident that the OMC altered but the MDD stayed constant at 2% plastic content. The MDD and OMC both began to change with the addition of the plastic at 4% and 6%. It was shown that MDD decreased as plastic concentration rose. The OMC was approximately 14% with an 8% increase in plastic content.

The cause of this is an increase in PET waste plastic; as more PET waste is added, more water must be consumed, making it harder to compact the composite specimen, which has the unfavorable effect of lowering MDD, shear strength, and CBR values. To get the best possible stabilization and compaction in expansive soils, it is crucial to carefully choose the percentage of PET plastic strips, as shown by the comparison of these results. To ensure that the plastic strips promote compaction without affecting the structural integrity of the soil, the ideal balance must be found.

4.4. Atterberg Limits

An essential tool for evaluating the adaptability and shrinkage properties of expansive soils, also known as shrink-swell soils, is the Atterberg test. These soils undergo substantial quantity fluctuations as a result of variations in moisture content, which could result in damage and instability in building operations. The test measures the Liquid Limit (LL) and Plastic Limit (PL) numerically, aiding in calculating the Plasticity Index. The Liquid Limit is crucial for determining the soil's propensity to swell and potential loss of stability when saturated. The Plastic Limit, the lower bound of moisture content, is essential for expansive soils, assessing vulnerability to shrinkage and cracking after drying. Three trials were conducted for the liquid limit test. The empty can mass was measured, wet dirt was placed, and the dry soil mass was calculated. By multiplying the ratio of water mass to soil solids by 100, the percentage of moisture (w) was calculated. The percentage of moisture at which the soil moves from a liquid to a solid state that is plastic is known as the liquid limit.

The most widely used standard for doing Atterberg's limit tests is ASTM D4318 - Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils. ASTM has produced numerous other standards as well. This standard offers instructions on how to calculate soils' liquid limit, plastic limit, and plasticity index. Engineers and geotechnical experts can acquire consistent and uniform findings for Atterberg's limit testing by adhering to the protocols defined in ASTM D4318. These findings are essential for classifying soils, establishing the appropriateness of soil for engineering purposes, and assessing how fine-grained soils behave under various moisture levels.

The plastic limit is the amount of water that can be molded into different shapes without disintegrating or showing substantial deformation. Moisture content is crucial in both tests, as it impacts soil consistency and behavior. Engineers and geotechnical experts can evaluate soil suitability for construction projects, forecast stress behavior, and make informed decisions about foundation design, stability, and compaction based on these tests.

Expansive soils are those whose volumes significantly alter as a result of differences in the amount of moisture present. These soils often contain clay minerals that can expand when exposed to moisture and contract when exposed to heat. Sandy silts, clayey silts, or inorganic silts with minimal flexibility make up the soils of the ML and MH categories. Loess-like soils and rock flours are also covered. When their LL is less than 50, micaceous and diatomaceous soils may cross over into the ML group, although in usually they belong to the MH group. Understanding the engineering qualities of expansive soils is crucial for construction projects.

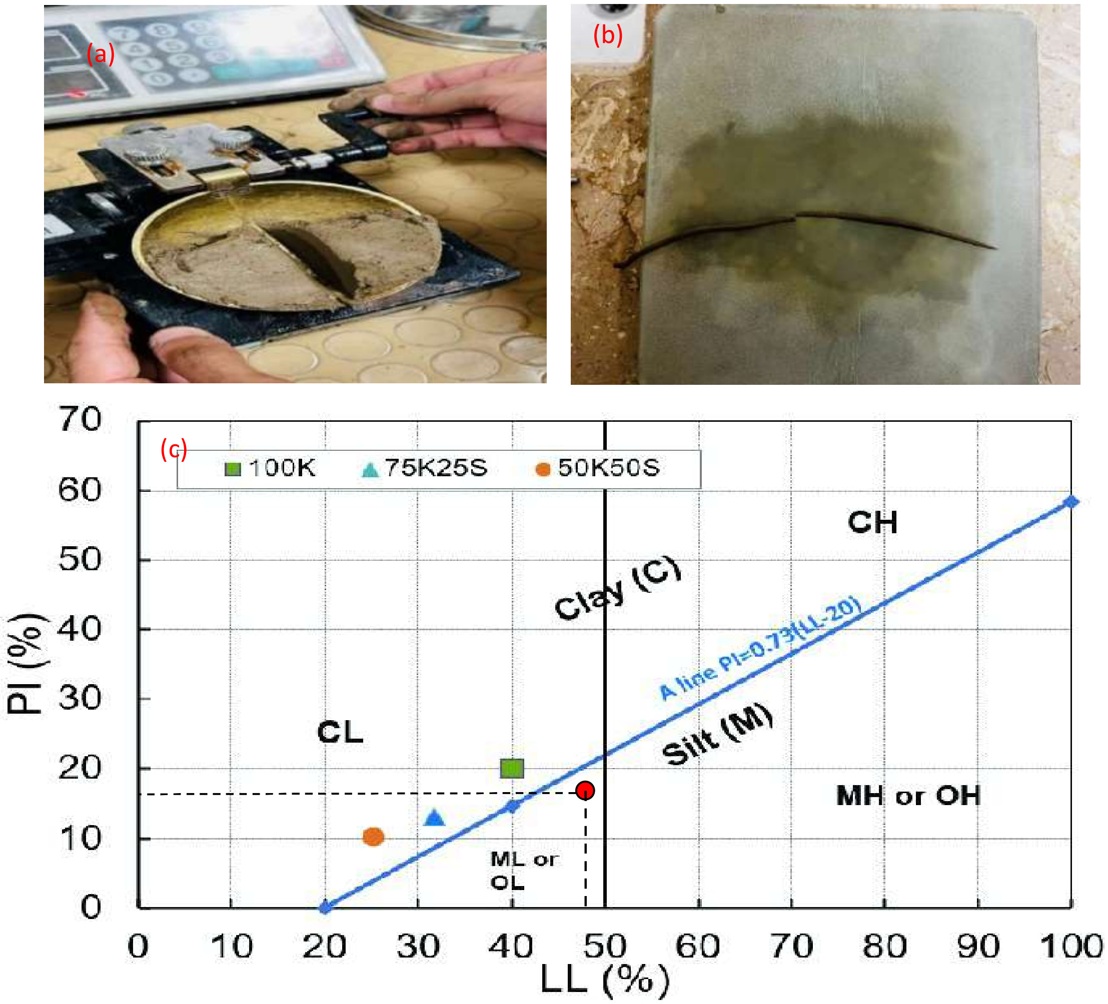


Figure 4.3. (a) liquid limit, (b) plastic limit Plastic limit and (c) liquid limit curve

The average plastic index of 17.4521 indicates that expansive soil exhibits plastic behavior over various moisture contents. The average liquid limit, 48.3800 as shown in table 4.3, represents the moisture content at which the expanding soil transforms from a liquid to a plastic condition. This value is crucial for characterizing the soil's behavior and understanding its potential for volume changes.

The liquid limit helps engineers and geotechnical experts assess the soil's ability to retain water and its sensitivity to swelling, which can significantly impact the stability and performance of buildings built on expansive soils. Strategies like soil stabilization, moisture barriers, and effective drainage systems can help reduce the risk of harm caused by expansive soils.

Table 4.3 results of Atterberg's limits

Sr.no	**trial**	**Liquid limit**	**Plastic index**
1	1	46.24	19.24
2	2	48.75	16.3
3	3	50.14	16.81
	Average	48.38	17.45

The liquid limit helps engineers and geotechnical experts assess the soil's ability to retain water and its sensitivity to swelling, which can significantly impact the stability and performance of buildings built on expansive soils. Strategies like soil stabilization, moisture barriers, and effective drainage systems can help reduce the risk of harm caused by expansive soils. Two important criteria are the liquid limit and the maximum amount of plastic, which are used to assess soil behavior. The amount of moisture in the soil at which it becomes semi-solid is represented by the threshold for plasticity, while the soil moisture level at which it grows increasingly liquid-like is represented by the liquid limit. The soil gets more plastic-like as the moisture content rises. The discrepancy between the liquid limit and plastic limit values yields the plasticity index (PI).

The average plastic index and liquid limit reveal important details about expansive soils. Engineers can use these values to determine the soil's potential for volume fluctuations and create mitigation strategies for risks associated with expansive soils during construction and long-term structural performance. Engineers and geotechnical experts can better understand the soil's flexibility, shrinkage traits, and potential for volume changes due to moisture variations.

4.5. Direct Shear Strength

A direct shear test is a frequently utilized lab test in geotechnical engineering to determine the parameters associated with the shear strength of soil or other granular materials. In order to properly design foundations, analyses slope stability, and complete earthwork projects, engineers must have a thorough understanding of the material's behavior under shear loading circumstances. Let's go over the specific justifications for using the direct shear test in greater detail. Find the soil sample's strength against shear parameters: calculating shear strength parameters of a soil sample is one of the direct shear test's main goals. These variables, which are critical for determining the stability and resistance to shear forces of the soil, include the cohesiveness (c) and the angle of internal friction(φ). The test yields useful information on the material's shear strength characteristics by subjecting the soil sample to controlled shear displacement.

The table 4.4 displays the results of a direct shear test on a soil sample, identifying its shear behavior under various typical stresses. It is divided into columns showing lateral deformation, shear load at different normal loads, normal stress, peak shear stress, and ultimate shear stress. The "Lateral Deformation" column displays the degree of internal shear deformation, while the "Shear Load at Normal Load" columns show the appropriate shear load values. The "Peak Shear Stress (kg/cm^2)" column displays the peak shear stress values, with the highest peak stress value being 0.16171875 kg/cm^2. The data indicates that the maximum peak stress occurs at a normal stress of 0.19203125 kg/cm^2.

Figure 4.4. Direct shear test with plastic

The table 4.4 displays the highest ultimate shear stress of 0.125 kg/cm^2, with a normal stress of 0.19203125 kg/cm^2. The maximum peak shear stress is recorded at 0.16171875 kg/cm2, and the maximum ultimate stress is 0.125 kg/cm^2. These numbers indicate the highest shear resistance points in time before the soil sample failed. It is crucial to understand the connection between normal stress and shear stress characteristics in geotechnical engineering to assess soil stability and strength. The table provided contains normal stress values for 2% plastic, corresponding to the highest peak and ultimate stress. To determine normal stress values, divide the shear load numbers by the 64 cm^2 area provided. The formula "Normal Stress (kg/cm^2)"equals "Shear Load (kg)" / Area, which can be used to determine the normal stress values for each data point.

In order to determine the highest values, we can next examine the "Peak Shear Stress (kg/cm^2)" and "Ultimate Shear Stress (kg/cm^2)" columns. According to the table, the peak shear stress can reach a maximum value of 11.6 kg/cm^2. Referring to the estimated normal stress values, we must locate the row where the peak shear stress is 11.6 kg/cm^2 in order to ascertain the appropriate normal stress value. Similar to this, the table does not explicitly state the maximum value of ultimate shear stress. Using the calculated normal stress values, we may find the highest ultimate shear stress value and establish the associated normal stress value. For the given data with 4% plastic, we may examine the provided table to establish the normal stress levels at which the highest peak shear stress and ultimate shear stress occur.

Table 4.4. Shear stress values at different percentages

Sr. no	**Normal Stress (kg/cm2**	**Peak Shear Stress (kg/cm2)**	**Ultimate Shear Stress (kg/cm2)**
		With soil only	
1	0	0	0
2	0.05140625	0.1171875	0.0703125
3	0.09828125	0.140625	0.1171875
4	0.19203125	0.16171875	0.125
		With 2% plastic	
5	0	0	0
6	0.05140625	0.1546875	0.125
7	0.09828125	0.171875	0.1484375
8	0.19203125	0.1875	0.165625
		With 4% plastic	
9	0	0	0
10	0.05140625	0.1328125	0.0828125
11	0.09828125	0.171875	0.125
12	0.19203125	0.19921875	0.178125
		With 8% plastic	
13	0	0	0
14	0.05140625	0.1171875	0.0703125
15	0.09828125	0.140625	0.1171875
16	0.19203125	0.16171875	0.125

The values are not stated directly when we look at the "Normal Stress (kg/cm^2)" column. However, by dividing the shear load values by the specified area, we can determine the normal stress values. We multiply the shear load values by the area to determine the normal stress. Assume that the area remains the same across all data points.

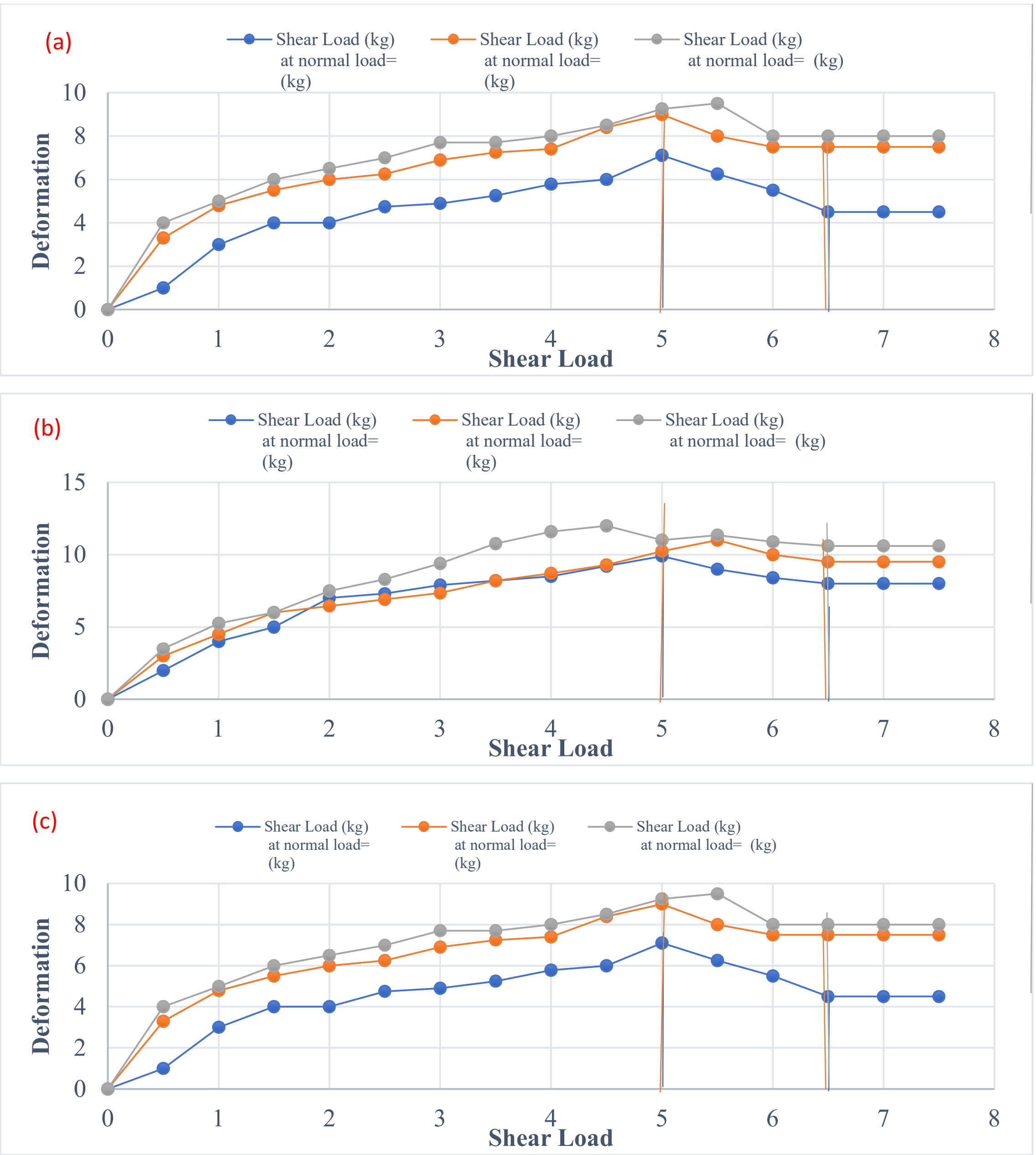


Figure 4.5. (a) shear load at 3.29, (b) shear load at 6.29, (c) shear load at 12.29

In order to determine the highest values, we can next examine the "Peak Shear Stress (kg/cm2)" and "Ultimate Shear Stress (kg/cm2)" columns. According to the table, the peak shear stress can reach a maximum value of 12.75 kg/cm2. Referencing the estimated normal stress values, we must locate the row where the peak shear stress is 12.75 kg/cm2 in order to ascertain the matching normal stress value and for further details or data check annexure B. Similar to this, the table does not explicitly state the maximum value of ultimate shear stress.

Using the calculated normal stress values, we may find the highest ultimate shear stress value and establish the associated normal stress value (Mehta et al, 2014). We can figure out the normal stress values connected to those places once we have determined the rows corresponding to the highest peak shear stress and ultimate shear stress. For the given data with 8% plastic, we may examine the provided table to establish the normal stress levels at which the highest peak shear stress and ultimate shear stress occur. The figures for typical stress, however, are not included in the table you gave. We require the computed normal stress values associated with each data point in order to determine the highest values of peak shear stress, ultimate shear stress, and their accompanying normal stress values. We cannot analysis the table to find the precise locations where the maximum values occur without the usual stress levels.

The soil sample was subjected to shearing forces along a predefined plane during the direct shear test. The sample was gradually subjected to the shear force till failure. Peak shear strength, shear displacement, and stress-strain behavior were all measured during the test. The soil samples with 4% plastic strip content among the evaluated percentages showed the highest shear strength values, according to the test results in the study on soil stabilization utilizing plastic bottle strips. This suggests that the soil's resilience to shearing pressures was improved as a result of the addition of 4% plastic bottle strips.

4.5. Unconfined Compressive Strength

A laboratory test called the Unconfined Compressive Strength (UCS) test is used to assess a soil sample's strength characteristics in a without restriction setting. It gauges the highest compressive stress a soil specimen can endure before failing or significantly deforming. Clay or silt are common cohesive soil types on which the UCS test is carried out. Expanding soils, often referred to as shrink-swell Specifically, soils undergo considerable volume changes in response to variations in the amount of water present. These soils frequently have minerals called clay, which, when exposed to water, can expand and swell eventually contracting again after drying. Projects involving geotechnical engineering and construction may experience serious issues as a result of this behavior. The UCS test is very useful for understanding expansive soils since it measures their stability and strength. The UCS test measures the maximum compressive stress that a piece of soil can withstand by applying axial compression to it until it fails. Understanding the soil's ability to support loads and its propensity to withstand deformation and structural failures depends heavily on this information.

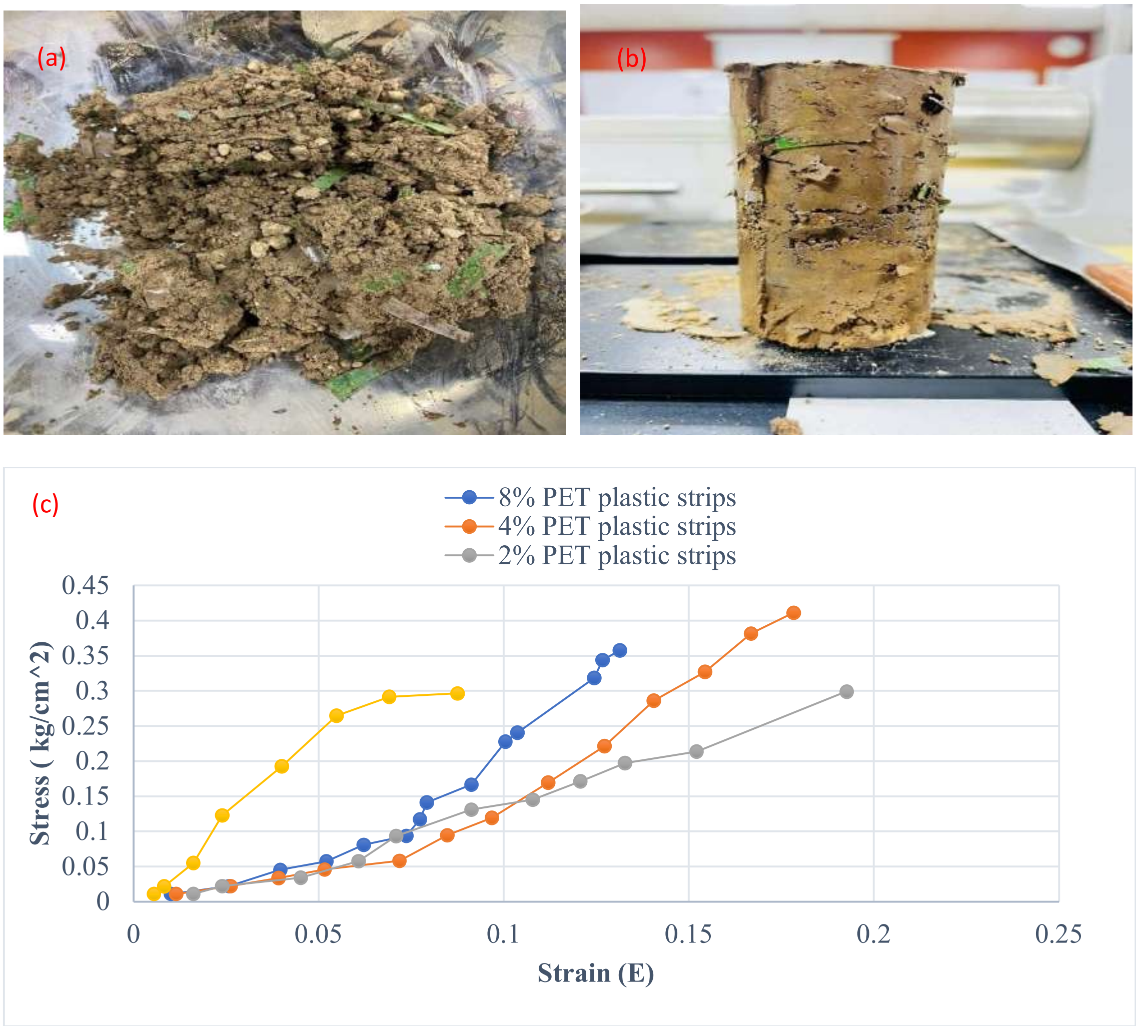


Figure 4.10. (a) sample preparation, (b) prepared sample with plastic for UCS test and (c) stress strain curve between different percentages

The table displays data from an unconfined compression test on a soil sample, gauging the stress-strain relationship. It includes information about strain (Ɛ), strain %, corrected area (A), load, and stress. The deformation dial reading (DR) represents the axial deformation, while the load dial reading (DR) shows the applied load. The sample deformation parameter (L) represents the measured length change due to the applied force. Strain values range from 0.0055 to 0.0876, with strain percentage values ranging from 0.552995% to 8.75576%. Corrected area (A) is used to determine stress, and load (kg) shows the weight of the applied load. Stress (kg/cm2) is computed by dividing the load by the adjusted area, displaying the force exerted per square inch of the soil sample.

Table 4.5. UCS Test values

sr.no	%age of strips	Max strain	Max Stress
1	0%	0.0876	0.2964593
2	2%	0.192626728	0.2990923
3	4%	0.178341014	0.4111439
4	8%	0.131336406	0.357736

Expansive soils have low UCS values due to high clay content and potential volume changes caused by moisture. Engineers and geotechnical experts can evaluate the stability and structural integrity of foundations, embankments, and other structures using the UCS test. Understanding the UCS of the soil can help mitigate potential problems caused by expanding soil behavior. The UCS test provides crucial information on the strength properties of soils, including expansive soils, aiding engineers in making informed decisions during design and construction phases. The data shows that load (Load DR), sample deformation (Sample Deformation L), strain (Strain), and strain percentage (Strain%) all rise as the deformation (Deformation DR) increases.

The greatest stress value is found at a load DR of 29, with a stress value of 0.357736 kg/cm2. The composition of the sample, which contains 8% plastic, is crucial for understanding the mechanical characteristics and behavior of a sample. The strain and strain percentage columns also shed light on the sample's deformation properties, with strain and strain percentage rising together with the deformation (Deformation DR). The corrected area (Corrected Area (A)) is a further consideration, taking into account the observed deformation and calculating precise stress readings.

The preceding figure and table make it evident that as plastic content increases, the unconfined compressive strength of the soil increases. However, up until 4% plastic content, when significant changes in the strength factor were seen, the strength factor began to decline. Because the bond between the plastic and the soil is not very strong, the deformation of the soil increases as the plastic concentration rises. The reinforced soil's elasticity limit is thereby raised, but some slight deformations are still seen on the same side (Mehta et al, 2014). The findings of this research indicate that the compressive strength of soil can be enhanced up to a certain point before it starts to decline once more, providing a precise limit if we want to reinforce the soil with plastic.

4.7. Summary

In conclusion, the test results showed how plastic bottle strips affected expansive soils. The soil's shear strength, flexibility, compaction characteristics, and particle size distribution were all impacted by the addition of plastic additives. Designing efficient engineering solutions and preventing potential problems related to expanding soils modified with plastic bottle strips require an understanding of these changes. The ideal proportion and use of plastic additives in expanded soil stabilization must be determined through additional research and study. Atterberg limits, it was found that as the proportion of plastic bottle strips grew, the soil's flexibility and moisture sensitivity declined. This shows that the presence of plastic additives decreased the soil's capacity to hold onto moisture and its flexibility. The results of the compaction tests indicate that the addition of plastic bottle strips changed the soil's overall density and compaction characteristics, which may have an impact on the soil's load-bearing capacity and settlement behavior.

Chapter 5: DISCUSSION

5.1. Background

Due to the growing demand for environmentally friendly and economically viable construction techniques, the topic of soil stabilization has attracted a lot of attention recently. The use of cement or chemical additives in traditional soil stabilization techniques has limitations, such as high prices and environmental problems. In order to increase soil stability, scientists and engineers have been looking into substitute materials and methods. The use of plastic bottle strips as fiber reinforcement in soil stabilization is one such creative strategy. Millions of plastic bottles end up in landfills or end up polluting our oceans and waterways. Polyethylene terephthalate (PET) bottles in particular are a major contributor to this problem. Reusing these abandoned bottles as building materials not only solves the issue of plastic waste but also provides a long-term answer for soil stabilization.

5.2. Lessons learnt from current Design Project

Current demonstration experiments focusing on soil stabilization employing plastic bottle strips as fiber reinforcement at various plastic concentrations, including 2%, 4%, and 8%, have given insightful information about the performance and efficacy of this method. In this research, it was investigated how different plastic concentrations affected the reinforced soil's mechanical characteristics, stability, and long-term behavior. We can better grasp the ideal plastic concentration for obtaining desirable soil stabilization effects by examining the lessons learnt from these operations. The impact of plastic content on the mechanical characteristics of the reinforced soil is one of the most important lessons that can be drawn from the current demonstration projects. This research has shown that the soil-bottle strip composite's tensile strength and shear resistance increase as the plastic content in the material increases.

The interlocking action of the strips increases the soil's capacity to support loads, which increases stability at higher plastic concentrations. It is crucial to remember that there is a critical level of plastic over which the advantages start to wane, presumably as a result of an increase in non-reinforced plastic particle concentration. The effect of plastic content on the compaction and workability properties of the reinforced soil is another important lesson learnt. The soil mixture's workability is often impacted by higher plastic concentrations, making it harder to accomplish adequate compaction. In order to maintain the ideal balance between workability and compaction, it is crucial to carefully manage the soil moisture content and plastic concentration. To achieve the desired density and reduce settlement or deformation concerns in the stabilized soil, adequate compaction is crucial.

Table 5. 1 Results of different lab tests

Description	Plastic Content 0%	Plastic Content 2%	Plastic Content 4%	Plastic Content 8%
MDD $^{(g/cm^3)}$	1.776	1.89	1.799	1.547
OMC (%)	12.5	14.35	11.25	13.9
UCS $^{(kg/cm^2)}$	0.2964	0.299	0.4111	0.3575
Shear Stress$^{(kg/cm^2)}$	0.111	0.1656	0.1781	0.125

Additionally, in the ongoing demonstration studies at various plastic concentrations, the long-term functionality and durability of the reinforced soil have been studied. Lower plastic concentrations, like 2%, have been found to be less stable and durable over the long term, especially in harsh weather circumstances. Higher plastic concentrations like 8%have demonstrated improved resilience to deformation and the effects of weathering. To assure the durability of the soil stabilization system, additional research is required to look into the ageing qualities and probable degradation of plastic bottle strips over lengthy periods of time. These projects have also taken into account the economic and environmental effects of various plastic concentrations. While better soil stabilization is achieved with higher plastic concentrations, the solution's cost and environmental impact may also increase as a result of the need for more plastic bottles. Therefore, for widespread adoption and effective implementation of this approach, it is essential to discover an optimal plastic concentration that strikes a compromise between performance, cost-effectiveness, and sustainability.

In conclusion, key points have been clarified by the lessons learnt from ongoing demonstration projects that focus on various plastic concentrations for soil stabilization employing plastic bottle strips as fiber reinforcement. The workability, durability, and economic viability of the reinforced soil are significantly influenced by the plastic concentration. Future applications and research might be focused on attaining the necessary soil stabilization effects while taking into account considerations such as cost, sustainability, and long-term performance by knowing the ideal plastic content and its impact on various elements.

5.3. Guidelines for practicing engineers

Enhancing soil stability and sustainability has been made possible by using plastic bottle strips as fiber reinforcement in soil stabilization. The efficiency of this method can be affected by differing plastic concentrations, according to recent studies. For practicing engineers involved in the planning and execution of soil stabilization projects employing plastic bottle strips, these findings offer helpful guidance. First, for the best soil stabilization, practicing engineers should think about integrating plastic bottle strips at a 4% concentration. It has been discovered that this concentration strikes a compromise between enhanced mechanical qualities and affordability. Increased stability is the result of the soil's tensile strength and shear resistance being improved by the 4% plastic concentration. Additionally, this concentration guarantees a significant decrease in plastic waste, supporting environmentally friendly building methods. The guidelines for practicing engineers are:

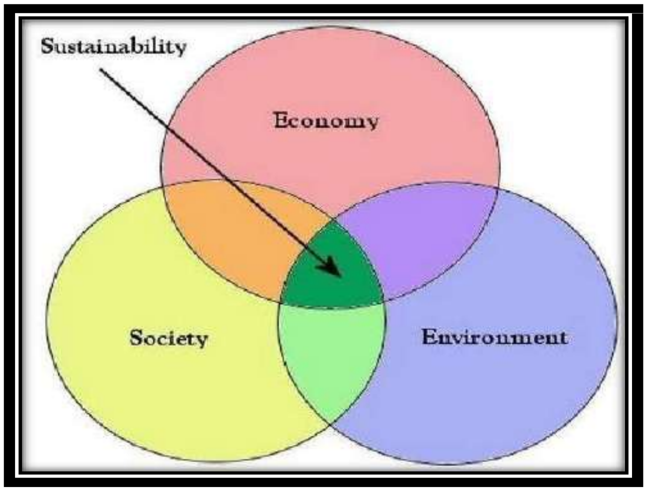


Figure 5.1 Sustainability model of UN

- Conduct thorough laboratory testing to assess the behavior of the soil with varied percentages of plastic bottle strips before using plastic bottle strip stabilization in the field. Tests including compaction, shear strength, and permeability should be run to determine the impact of various strip percentages on the characteristics of the soil.
- The best plastic bottle strip composition is: According to laboratory tests, the maximum values for compaction, shear strength, and other important factors are often found at 4%

plastic bottle strip content. Engineers are encouraged to prioritize this proportion because it will probably produce the best results.

- Despite the fact that 4% is thought to be the ideal amount, it is important to take into account the particulars of the site and the soil in question. If alterations to the plastic bottle strip composition are required, they should be made after considering variables such soil type, moisture content, and any current stability difficulties.
- Installation instructions: For soil stabilization to be successful, plastic bottle strips must be installed correctly. For the soil to provide the appropriate reinforcement, make sure the strips are distributed evenly and are sufficiently buried. To facilitate effective load transmission and enhanced performance, pay close attention to spacing and direction.
- Implement quality control procedures throughout construction to ensure that the required percentage of plastic bottle strips is appropriately included. Regular observation and inspection can aid in spotting any deviations or consistency issues and enable quick corrective action.
- Monitoring over an extended period of time is necessary to evaluate the efficacy and resilience of the soil stabilization strips made from plastic bottles. Regular site inspections and evaluations can offer insightful information about the technique's performance over time and permit essential tweaks or maintenance measures, if necessary.

It is crucial to remember that these advices are meant to be generic. The individual needs and circumstances of each project and location could necessitate modifying the plastic bottle strip's composition and method of application. Additional information and advice unique to the project can be obtained by consulting geotechnical engineers and experts with knowledge of soil stabilization. Engineers can use this information to build maintenance plans that will maintain the soil stabilization system's effectiveness. Finally, in order to promote acceptance, knowledge exchange, and support for the use of plastic bottle strips as a long-term soil stabilization solution, practicing engineers should interact with stakeholders, such as local people, engineers, researchers, and environmental organizations.

5.4. Summary

The article focuses on the lessons discovered from ongoing demonstration projects and explores the use of plastic bottle strips as fiber reinforcement for soil stabilization. In order to evaluate the efficiency of plastic bottle strips in improving soil stability, the projects investigated their use at various concentrations, including 2%, 4%, and 8%. The knowledge gained from these research offers practical engineers working on soil stabilization projects with plastic bottle strips useful information. Before employing plastic bottle strip reinforcement, practicing engineers should conduct exhaustive site inspections and soil testing to guarantee successful implementation. While thorough soil testing assists in identifying the ideal design parameters, site characterization aids in understanding the soil composition and behavior. During installation, it is essential to arrange the strips correctly, compact them, and connect them to the soil matrix. To guarantee the integrity and long-term effectiveness of the stabilized soil, quality control procedures should be put in place, such as routine monitoring and inspection.

Chapter 6: CONCLUSION AND RECOMMENDATION

6.1. Conclusions

Using plastic bottle strips as fiber reinforcement for soil stabilization is a viable way to increase stability and handle plastic waste issues. The takeaways from the present demonstration projects emphasize how crucial it is to take into account the ideal plastic concentration, do in-depth site assessments, use correct installation techniques, and undertake long-term monitoring. The following conclusion we get after completion of this DP:

- Limited study has been done and is still being done on using PET plastic waste to strengthen clay. Clay-PET plastic waste composite's potential for use in the civil engineering sector was successfully studied, and new information was added.
- Increasing the amount of plastic bottle strips causes changes in the maximum dry density (MDD) and optimum moisture content (OMC). The MDD tends to rise along with the plastic content, indicating increased compaction properties of the stabilized soil.
- The medium expansiveness of the soil type suggests a moderate susceptibility to fluctuations in moisture content. Utilizing plastic bottle strips for stabilization might assist regulate moisture variations and lessen the possibility of soil expansion or contraction.
- At 4% plastic strip content, the maximum load-bearing capacity is attained. This shows that this ratio provides the best compromise between soil strength development and reinforcement, resulting in increased stability and load-bearing capability.
- The maximum shear strength values are found at 4% plastic strip content. This demonstrates that this percentage offers the best resistance to shearing pressures and stronger shear strength qualities when compared to other percentages.
- It became apparent that as soil content of plastic rose, the compressive strength and shear strength correspondingly to 4% inclusion before beginning to decline, indicating the limit of plastic inclusion.
- To achieve uniform reinforcement and the correct soil density, proper installation methods are essential. These include consistent strip placement, compaction, and bonding. Understanding the behavior of the reinforced soil under diverse conditions

and ensuring continued efficacy need long-term monitoring and evaluation of its performance.

According to the research, clay-PET plastic waste mixtures can be used as a bio-stabilization substance to reinforce slopes, roadways, or highway embankments. To assess the applicability and design criteria, however, rigorous site inspections and soil testing are needed before this technology can be successfully applied. To achieve uniform reinforcement and the right soil density, proper installation techniques are essential. These include consistent strip placement, compaction, and bonding. The performance of the reinforced soil under various situations must also be continuously monitored and evaluated over time to ensure its efficacy. This underlines the significance of continuous evaluation and comprehension of the evolution of clay-PET waste composite behavior.

6.2. Recommendations

The following are the recommendations we suggest after this project:

- The title for future project is “Enhancing Soil Stabilization by Optimizing Plastic Bottle Strip Dimensions”, To obtain the most effective soil stabilization at the lowest possible cost and to support environmentally friendly building methods, it is essential to optimize the dimensions of plastic bottle strip. The promise of plastic bottle strips as an environmentally acceptable way to enhance soil engineering qualities while reducing plastic waste and environmental effect is increased by this research's determination of the best dimensions.
- Another title for future project is “Analysis of Plastic Bottle Strips and Fly Ash in Comparison for Soil Stabilization”, The evaluation of plastic bottle strips and fly ash for soil stabilization provides insightful information on the viability of eco-friendly substitutes, assisting in the development of sustainable infrastructure. Engineers can choose the most effective and ecologically responsible soil stabilizing technique by having a thorough understanding of their respective performance and effectiveness.

References

Adane, L. and D. Muleta, Survey on the usage of plastic bags, their disposal and adverse impacts on environment: *A case study in Jimma City, Southwestern Ethiopia. Journal of Toxicology and Environmental Health Sciences*, 2023. 3(8): p. 234-248.

Amena, S. (2022). Utilizing solid plastic wastes in subgrade pavement layers to reduce plastic environmental pollution. *Cleaner Engineering and Technology.*

Amena, S., & Chakeri, D. (2022). A Study on the effects of plastic waste strips and lime on strength. *Advances in Civil Engineering*, 6 pages.

Ashok Kumar, T., Thyagaraj, T., Robinson, R.G., (2018), Distress of an industrial building constructed on an expansive soil: A case study from India, *Proceedings of the Institute of Civil Engineers Forensic Eng*ineering. 171 (3) 121–126

Biswas, S., S. Kindo, and A. Patnaik, Effect of fiber length on mechanical behavior of coir fiber reinforced epoxy composites. *Fibers and Polymers*, 2011. 12(1): p. 73- 78.

Emberton, J. R., & Parker, A. (2017). The problems associated with building on land fill sites. *Waste management and research.*

Eriksen, M.K. , Astrup , T.F. (2019), Characterization of source-separated, rigid plastic waste and evaluation of recycling initiatives : *Effects of product design and source-separation system Waste Management*, 87, pp. 161-172.

Gangwar, P., & Tiwari, S. (2023). Stabilization of soil with waste plastic bottles. *Materials Today: Proceedings.*

Ghavami, K., R.D. Toledo Filho, and N.P. Barbosa, Behaviour of composite soil reinforced with natural fibres. *Cement and Concrete Composites*, 1999. 21(1): p. 39-48.

Hashem ,F.S. , Razek, T.A. , Mashout,H.A, (2019), Rubber and plastic wastes as alternative refused fuel in cement industry: *Construction Building Materials*., 212, pp. 275-282

Hausmann, M.R., 1990. *Engineering principles of ground modification*, McGraw-Hill Ryerson, Limited.

Hejazi, S. M., Sheikhzadeh, M., Abtahi, S. M., & Zadhoush, A. (2012). A simple review of soil reinforcement by using natural and synthetic fibers. *Construction and Building Materials*, 100-116.

Ilyas, M., Ahmad, W., Khan, H., Yousaf, S., Khan, K. & Nazir, S. (2018). Plastic waste as a significant threat to environment–a systematic literature review. *Reviews on Environmental Health.*

Jill, T., 2014. *The different types of plastics and classification*, https://tropicalcommons.co/wp-content/uploads/2019/01/Different_plastic_polymer_types.pdf.

Karmacharya, R., & Acharya, I. P. (2017). Reinforcement of soil using recycled polyethylene terephthalate (PET) bottle strips. *Proceedings of IOE Graduate Conference*.

Kazi, A. M. (2021). Experimental investigation of clayey soil mixed with rubber flash. *International Journal of Engineering Research & Technology (IJERT).*

Kianimehr M, Shourijeh PT, Binesh SM, Mohammadinia A, Arulrajah A. (2019). Utilization of recycled concrete aggregates for light-stabilization of clay soils. *Construction Build Materials*.

Koohmishi, M., & Palassi, M. (2022). Mechanical properties of clayey soil reinforced with PET considering the influence of lime-stabilization. *Transportation Geotechnics*.

Kumar, T., Panda, S., Hameed, S., & Maity, J. (2018). Behaviour of soil by mixing of plastic strips. *International Research Journal of Engineering and Technology*.

Lambe and Moh, Effects of salt additives in highly plastic soils. *European Journal of Soil Mechanics and Foundation Engineering*, 2005. 18: p. 823-829.

Luwalaga, J. G. (2015). Analysing the behaviour of soil reinforced with polyethylene terephthalate (PET) plastic waste. *Research Report.*

Makusa, G.P., Soil stabilization methods and materials in engineering practice: *State of the art review*. 2013: Luleå tekniska universitet.

Malik, P., & Sudipta, K. (2023). A comprehensive review of soil strength improvement using geosynthetics. *Materialstoday proceedings*.

McLain, K.W., Optimizing the value of soil compaction testing quality assurance and control using stochastic life cycle cost, *comparative and statistical analysis*. 2015.

Mehta, K.S., et al., Analysis of engineering properties of black cotton soil & stabilization using by lime. *Journal of Engineering Research and Application*, 2014. 4(5): p. 25-32.

Murthy, V., *Principles and practices of soil mechanics and foundation engineering*. New York: Marcek Decker INC, 2002.

Nelson, J. and D.J. Miller, Expansive soils: *problems and practice in foundation and pavement engineering*. 1997: John Wiley & Sons.

Prabakar, J. and R. Sridhar, Effect of random inclusion of sisal fibre on strength behaviour of soil. *Construction and Building Materials*, 2002. 16(2): p. 123-131.

Puppala, A.J. and C. Musenda, Effects of fiber reinforcement on strength and volume change in expansive soils. *Transportation Research Record*, 2000. 1736(1): p. 134-140.

Rahimi, M., Omran, M. P., Tafreshi, S. N., & Norouzi , A. (2023). Experimental Investigation of the Behavior of Soil Reinforced with Used PET Bottles. *Geotechnical and Geological Engineering*, 41, pages1909–1920.

Ranjan, G. and B.G. Rao. Skirted granular piles for ground improvement. in Proc., *VIII European Conf. on Soil Mech. and Found*. Eng., Halainki. 1983.

Sahoo, S., & Singh, S. P. (2022). Strength and durability properties of expansive soil treated with geopolymer and conventional stabilizers. *Construction and Building Material*s.

Sherwood, P., *Soil stabilization with cement and lime*. 1993.

Sridharan, A. and K. Prakash, Classification procedures for expansive soils. *Proceedings of the Institution of Civil Engineers-Geotechnical Engineering*, 2000. 143(4): p. 235-240.

Stab, E.S., Development of design and construction methods to stabilize soft organic soils: *Design guide for soft soil stabilization*. CT97-0351, European Commission, Industrial and Materials Technologies Programme (Rite-EuRam III) Bryssel, 2002.

Tafreshi, S. M., Malekshah, A. R., Rahimi, M., & Dawson, A. (2022). Bearing capacity improvement using soil-filled post-consumer PET bottles. *Geosynthetics International*, 29.

Tang, C., et al., Strength and mechanical behavior of short polypropylene fiber reinforced and cement stabilized clayey soil. *Geotextiles and Geomembranes*, 2007. 25(3): p. 194-202.

Theng, B., Clay-polymer interactions: summary and perspectives. *Clays and Clay Minerals*, 1982. 30(1): p. 1-10.

Toledo, A. and B. Burlingame, (2006), Biodiversity and nutrition: A common path toward global food security and sustainable development. *Journal of food composition and analysis*, pp.477-483

White, M.A. and D.C. MacLaren, Cement: Its Chemistry and Properties. *Journal of chemical education*, 2003. 80(6): p. 623-635.

White, W.A., Atterberg plastic limits of clay minerals. American Mineralogist: *Journal of Earth and Planetary Materials*, 1949. 34(7-8): p. 508-512.

Yetimoglu, T., J.T. Wu, and A. Saglamer, Bearing capacity of rectangular footings on geogrid-reinforced sand. *Journal of Geotechnical Engineering*, 1994. 120(12): p. 2083-2099.

ANNEXURE A

Step wise procedures

Particle distribution test

By this test we find one specific gain size of soil and bottle stirps which we used in the other following tests. The following procedure will be used:

- Weigh a sample of dry dirt that weighs at least 500gr.
- Make a note of the weights of the pan and sieve that will be used for the analysis. Each sieve needs to be properly cleaned before the test.
- Start with the sieves with the largest openings and arrange them in ascending order. As a result, the No. 4 sieve ought to go on top, and the No. 200 sieve ought to go at the bottom of the stack.
- Place a cap or lid on top of the top sieve after inserting the soil sample there.
- Shake the stack in a mechanical shaker for ten minutes.
- After removing the sieve stack from the shaker, weigh each sieve and the pan at the bottom.

Compaction test

The stepwise procedure of compaction test:

- Collect a sample of the stratified soil.
- Determine the weight of the Proctor mold using the base and collar extension.
- Assemble the compaction tool.
- Cover the mold with three layers of earth.
- To compact the earth, apply 25 equal blows with a hammer.
- Gently remove the base and collar extension of the collar without disturbing the soil.
- Determine the combined weight of the soil and the Proctor mold.
- Dry the soil in the oven for 12 hours to assess its moisture level.

Atterberg limit

The stepwise procedure of Atterberg limit test:

- The standard grooving tool should be used to make a groove in the middle of the soil paste before filling the cup with it.

- The cup should be raised using the crank-operated came to a height of 10mm, then lowered. Keep track of the number of blows and the volume of water required to fill the groove to a depth of 12.7 mm.
- For the same soil with various moisture contents, at least three times should elapse between each stage.
- Plot the percentage of soil moisture content and the corresponding number of blows on a semi-logarithmic graph. The best-fit straight line should join the plotted points.
- N 25, which was the moisture content corresponding to the soil's liquid limit, was.

Plastic limit

The water content at which a soil transitions from a plastic to a semisolid form is known as the Plastic Limit (PL or wPL), sometimes known as the lower plastic limit. By manually rolling an ellipsoidal-sized soil mass repeatedly on a non-porous surface, the plastic limit test is carried out. The water content at which a thread of soil simply crumbles when it is carefully rolled out to a diameter of 3 mm (1/8") is known as the plastic limit, according to Casagrande. The soil is too damp if the thread breaks at a diameter less than 3 mm. The soil is too dry to be plastic if the thread crumbles at a diameter higher than 3 mm. The test can then be repeated after molding the sample again.

Direct shear test

The stepwise procedure of direct shear test

- Determine the initial soil weight.
- The diameter and height of the shear box should be measured.
- Place the shear box into the shearing apparatus.
- Stabilize the bottom half of the shear box by tightening the two screws.
- To assemble the shear box, combine the porous stone and the gripper disc.
- Put the sample inside the container and then add the filter paper, porous stone, and loading cap.
- Weigh the remaining soil to determine the sample's mass.
- reducing the shear force to 0.

- Both the horizontal and vertical initial dial gauges are empty.
- Position the vertical load.
- the upward displacement caused by consolidation.
- Select a speed for the shearing tool.
- start the shearing process.
- Measure the shearing rate often until the horizontal deformation surpasses 10% to 15% of the starting diameter or the shear stress peaks and diminishes.

Unconfined compression test

The process will be as follows:

- The large mold will be filled with the appropriate density and water content for the soil sample.
- A sampling tube will be filled with the enormous mold.
- The sampling tube will be used to collect the soil sample. For unaffected samples, the sampling tube will be inserted into the clay sample.
- The soil sample will be soaked in the sampling tube using an appropriate technique.
- The broken mold will be covered in a thin layer of oil. The mold will be weighed, as intended.
- The sample will be taken out of the sampling tube and put into the split mold using the sample extractor and knife.
- The specimen's ends will be clipped before being placed in the split mold. The mold and specimen will be weighed.
- The specimen will be removed from one of the two portions of the split mold.
- After the soil sample's initial length, diameter, and weight are calculated using Vernier Calipers, it will be set on the bottom plate of the loading device.
- The top plate is moved till it comes into contact with the specimen.
- The dial gauge is adjusted to zero and the proving ring gauge is seated. • Axial strain is created by compression load at a rate of 0.5 to 2 percent per minute, resulting in failure in 5 to 10.
- The readings from the dial gauge and the proving ring will also be recorded. The reading can be taken at strains of 0, 0.1, 0.2, 0.5, 1, 2, 3, 4, 5, 6, 8, 10, 12, 14, 16, 18 and 20

percent. The reading can be taken every 30 seconds for strains under 6%, every 60 seconds for strains between 6% and 12%, and roughly every 2 minutes for strains over 12%.

- The compression load (force) value will be taken 0.5 mm apart from the deformation dial reading.
- The test will proceed until clearly defined failure surfaces have formed, the stress-strain curve has passed its peak, or an axial strain of 20% has been reached.
- The angle between the failure surface and the horizontal is measured, if it is possible.

The specimen's water content is assessed after a sample from the failure zone of the specimen is collected.

ANNEXURE B1

Experimental Data

Atterberg limits

Table B.1.1. Atterberg limits (Liquid limits & plastic limit results)

Liquid limit				
Trial No.	Symbol	1	2	3
Mass of empty can (gm)	W4	12	14	10
Mass of can + wer soil (gm)	W5	37	44	42
Mass of can + dry soil (gm)	W6	28.7	33.4	30.5
Mass of Water (gm)	Ww	8.3	10.6	11.5
Mass of Soil Solids (gm)	Ws	16.7	19.4	20.5
Moisture Content (%)	w=(Ww/Ws) x100	46.2453	48.7514	50.1435
No. of blows	N	37	47	43

Plastic limit				
Trial No.	Symbol	1	2	3
Mass of empty can (gm)	W4	10	14	12
Mass of can + wer soil (gm)	W5	34	34	38
Mass of can + dry soil (gm)	W6	28.6	29.1	31.5
Mass of Water (gm)	Ww	5.4	4.9	6.5
Mass of Soil Solids (gm)	Ws	18.6	15.1	19.5
Moisture Content (%)	w=(Ww/Ws) x100	27	32.45033	33.33333
Plastic index	19.2453	16.30107	16.81017	
Average liquid limit	48.38006667			
Plastic index	17.45217851			

ANNEXURE B2

Compaction test

Table 4.4. Compaction test with soil only

With soil Only				
Trial No.	Symbol	1	2	3
Mass of the mold (gm)	W1	3286	3286	3286
Mass of mold +Compacted soil (gm)	W2	5125	5220	5165
Volume of mold (cm^3)	V	943.9546	943.9546	943.9546
Weight of wet compacted soil (gm)	W3=W2-W1	1839	1934	1879
Wet Unit Weight (g/cm^3)	γ	1.948187	2.048827	1.990562
Dry Unit Weight (g/cm^3)	γd=γ/(1+w/100)	1.74665	1.77565	1.669503
Mass of empty can (gm)	W4	14	12	14
Mass of can + wer soil (gm)	W5	43	42	45
Mass of can + dry soil (gm)	W6	40	38	40
Mass of Water (gm)	Ww	3	4	5
Mass of Soil Solids (gm)	Ws	26	26	26
Moisture Content (%)	w=(Ww/Ws) x100	11.53846	15.38462	19.23077
Maximum Dry Density	MDD	1.77565	g/cm^3	
Optimum Moisture Content	OMC	12	%	

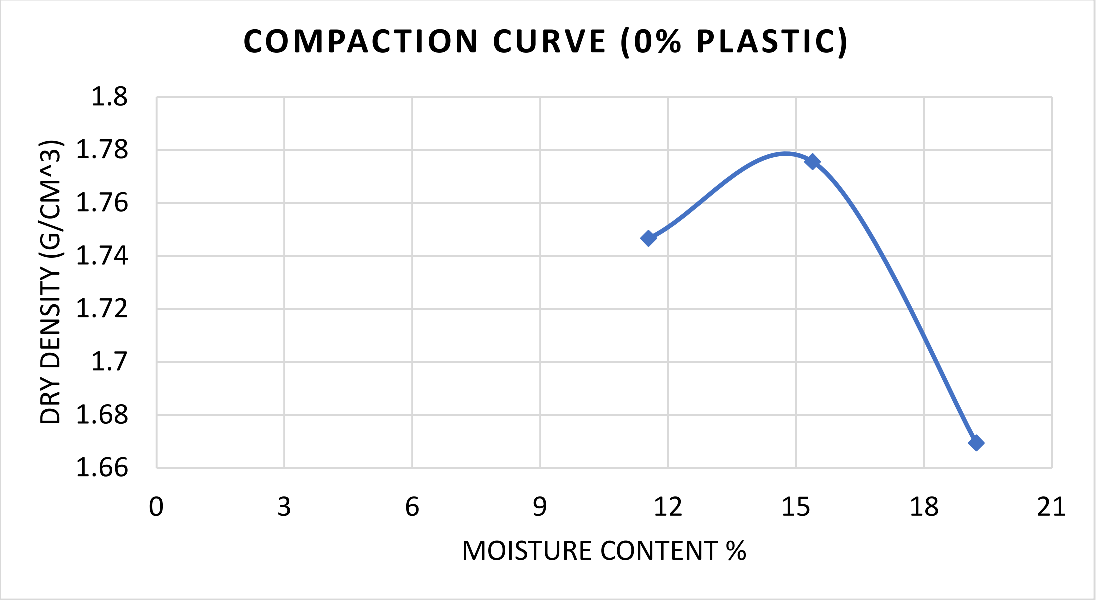


Figure 4.4.1 Compaction curve with soil only

Table 4.5. Compaction test with 2% plastic

With 2% plastic strips				
Trial No.	Symbol	1	2	3
Mass of the mold (gm)	W1	3286	3286	3286
Mass of mold +Compacted soil (gm)	W2	5095	5198	5134
Volume of mold (cm^3)	V	943.9546	943.9546	943.9546
Weight of wet compacted soil (gm)	W3=W2-W1	1809	1912	1848
Wet Unit Weight (g/cm^3)	γ	1.916406	2.025521	1.957721
Dry Unit Weight (g/cm^3)	γd=γ/(1+w/100)	1.772675	1.784388	1.678047
Mass of empty can (gm)	W4	14	12	10
Mass of can + wer soil (gm)	W5	54	54	52
Mass of can + dry soil (gm)	W6	51	49	46
Mass of Water (gm)	Ww	3	5	6
Mass of Soil Solids (gm)	Ws	37	37	36
Moisture Content (%)	w=(Ww/Ws) x100	8.108108	13.51351	16.66667
Maximum Dry Density	MDD	1.89	g/cm^3	
Optimum Moisture Content	OMC	14.2	%	

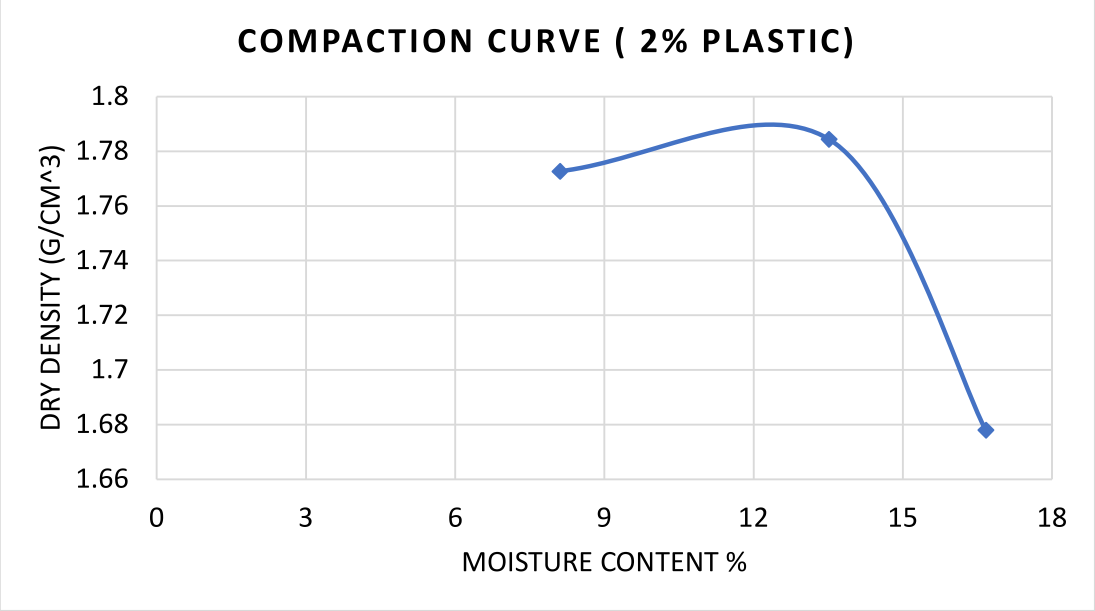


Figure 4.4.2 Compaction curve with 2% plastic strips

Table 4.6. Compaction test with 4% plastic

With 4% plastic strips

Trial No.	Symbol	1	2	3
Mass of the mold (gm)	W1	3286	3286	3286
Mass of mold +Compacted soil (gm)	W2	5166	5342	5382
Volume of mold (cm^3)	V	943.9546	943.9546	943.9546
Weight of wet compacted soil (gm)	W3=W2-W1	1880	2056	2096
Wet Unit Weight (g/cm^3)	γ	1.991621	2.178071	2.220446
Dry Unit Weight (g/cm^3)	γd=γ/(1+w/100)	1.834388	1.960264	1.903239
Mass of empty can (gm)	W4	12	10	10
Mass of can + wer soil (gm)	W5	50	50	52
Mass of can + dry soil (gm)	W6	47	46	46
Mass of Water (gm)	Ww	3	4	6
Mass of Soil Solids (gm)	Ws	35	36	36
Moisture Content (%)	w=(Ww/Ws) x100	8.571429	11.11111	16.66667
Maximum Dry Density	MDD	1.72	g/cm^3	
Optimum Moisture Content	OMC	11.5	%	

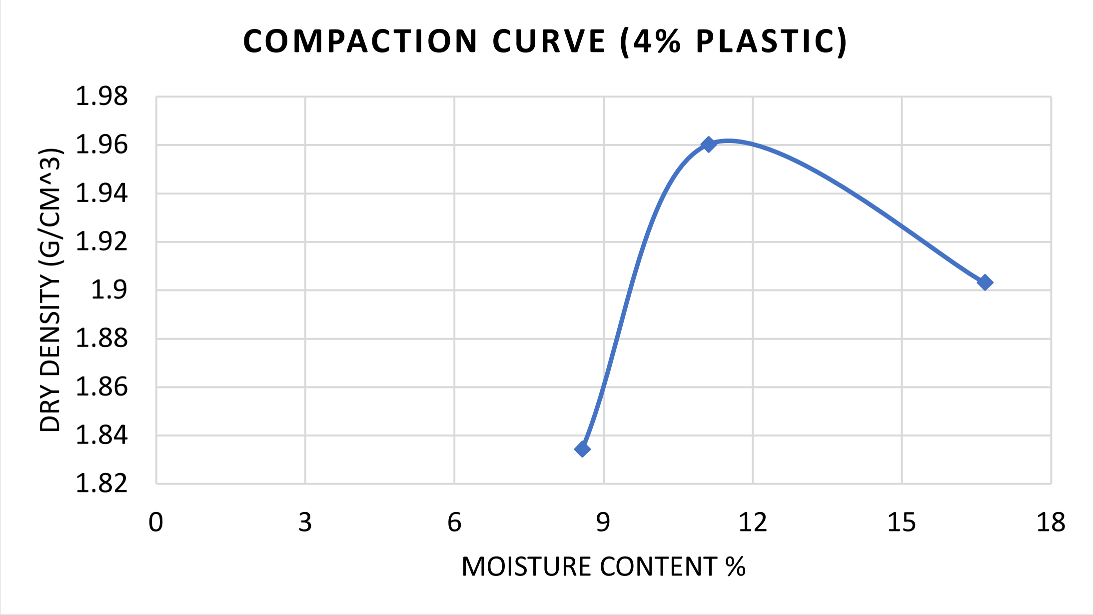


Figure 4.4.3 Compaction curve with 4% plastic strips

Table 4.7. Compaction test with 8% plastic

With 8% plastic strips				
Trial No.	Symbol	1	2	3
Mass of the mold (gm)	W1	3286	3286	3286
Mass of mold +Compacted soil (gm)	W2	5164	5298	5386
Volume of mold (cm^3)	V	943.9546	943.9546	943.9546
Weight of wet compacted soil (gm)	W3=W2-W1	1878	2012	2100
Wet Unit Weight (g/cm^3)	γ	1.989502	2.131458	2.224683
Dry Unit Weight (g/cm^3)	γd=γ/(1+w/100)	1.872473	1.907094	1.890981
Mass of empty can (gm)	W4	10	12	10
Mass of can + wer soil (gm)	W5	44	50	50
Mass of can + dry soil (gm)	W6	42	46	44
Mass of Water (gm)	Ww	2	4	6
Mass of Soil Solids (gm)	Ws	32	34	34
Moisture Content (%)	w=(Ww/Ws) x100	6.25	11.76471	17.64706
Maximum Dry Density	MDD	1.6729	g/cm^3	
Optimum Moisture Content	OMC	14	%	

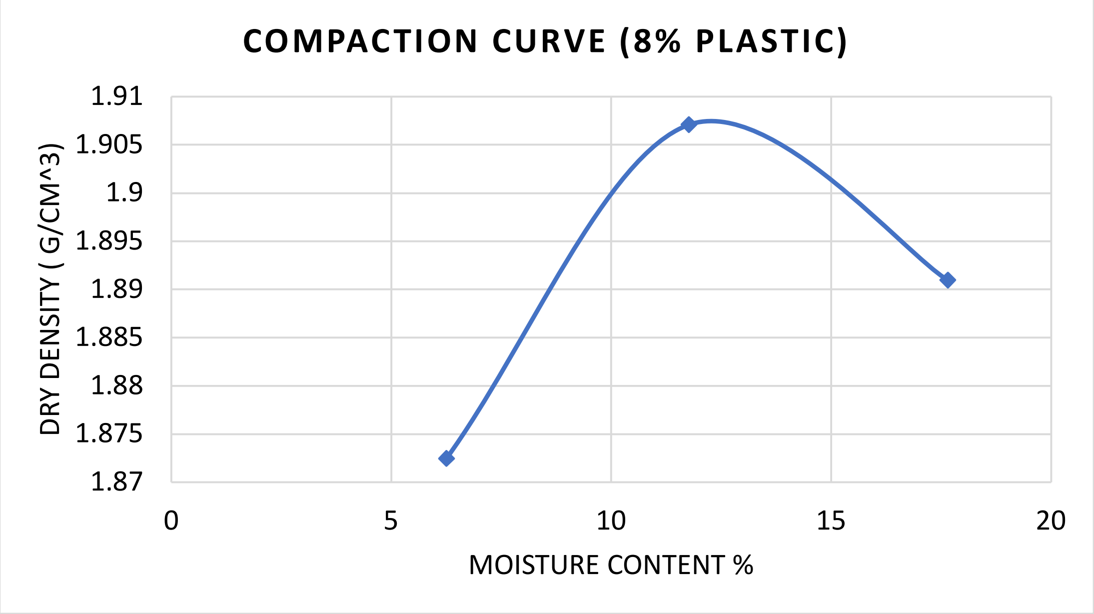


Figure 4.4.4 Compaction curve with 8% plastic strips

ANNEXURE B3

Unconfined compression test

Table 4.8. UCS test with soil only

WITH SOIL ONLY

Unconfined Compression Test Data (Deformation Dial: 1 unit = 0.01mm;

Load Dial: 1 unit = 0.2196 kg)

Deformation DR	Load DR	Sample Deformation ΔL (mm)	Strain (Ɛ)	Strain %	Corrected Area (A)	Load (kg)	Stress (kg/cm2)
12	1	0.12	0.0055	0.552995	20.02924	0.2196	0.010964
18	2	0.18	0.0083	0.829493	19.97431	0.4392	0.0219882
35	5	0.35	0.0161	1.612903	19.82032	1.098	0.0553977
52	11	0.52	0.0240	2.396313	19.66868	2.4156	0.1228146
87	17	0.87	0.0401	4.009217	19.36367	3.7332	0.192794
119	23	1.19	0.0548	5.483871	19.09297	5.0508	0.2645372
150	25	1.5	0.0691	6.912442	18.83784	5.49	0.2914346
190	25	1.9	0.0876	8.75576	18.51856	5.49	0.2964593

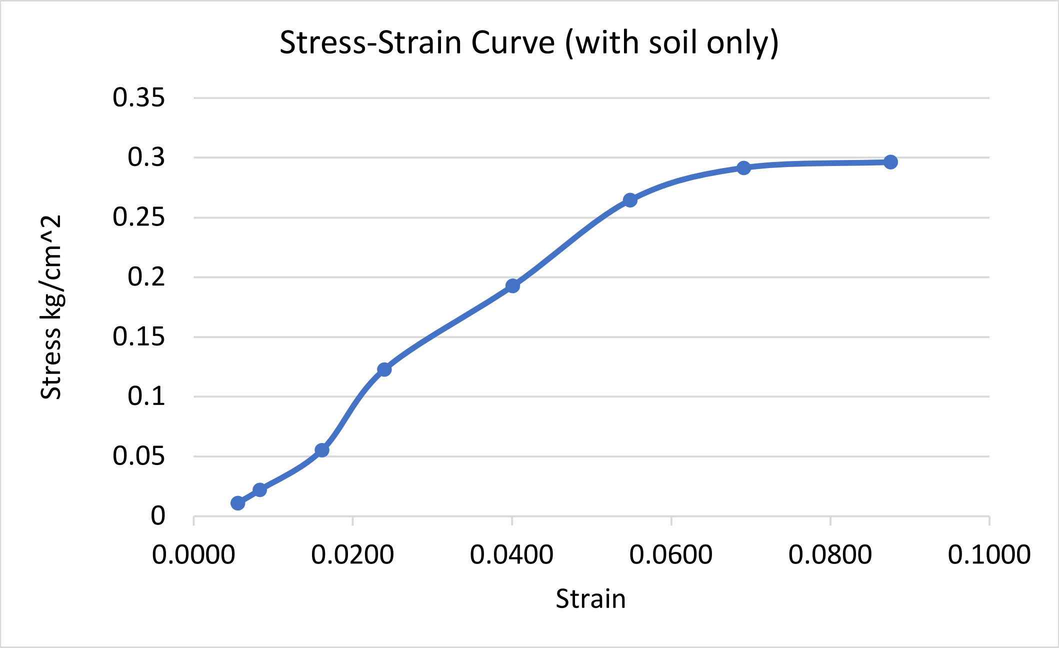


Figure 4.5.1 Stress strain curve with soil only

Table 4.9. UCS test with 2% plastic strips

2% PLASTIC

Deformation DR	Load DR	Sample Deformation ΔL (mm)	Strain (Ɛ)	Strain %	Corrected Area (A)	Load (kg)	Stress (kg/cm2)
35	1	0.35	0.016129	1.612903	19.82032	0.2196	0.0110795
52	2	0.52	0.023963	2.396313	19.66868	0.4392	0.0223299
98	3	0.98	0.045161	4.516129	19.26975	0.6588	0.0341883
132	5	1.32	0.060829	6.082949	18.98514	1.098	0.0578347
154	8	1.54	0.070968	7.096774	18.80542	1.7568	0.0934199
198	11	1.98	0.091244	9.124424	18.456	2.4156	0.1308843
234	12	2.34	0.107834	10.78341	18.17962	2.6352	0.1449535
262	14	2.62	0.120737	12.07373	17.97031	3.0744	0.1710822
288	16	2.88	0.132719	13.27189	17.78023	3.5136	0.1976128
330	17	3.3	0.152074	15.20737	17.48152	3.7332	0.2135512
418	23	4.18	0.192627	19.26267	16.88709	5.0508	0.2990923

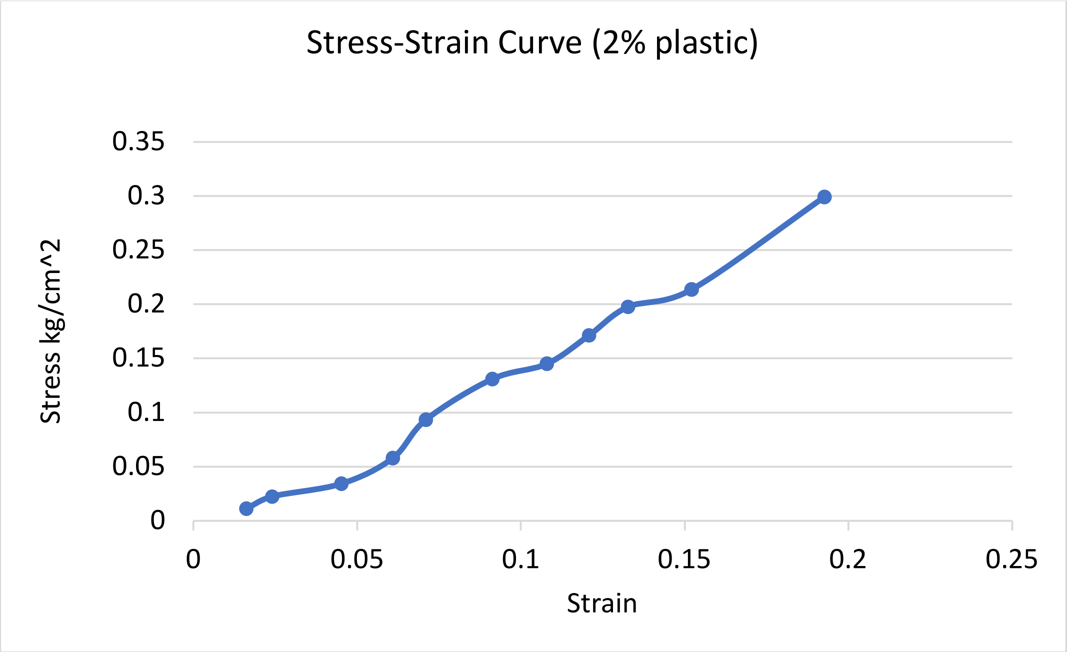


Figure 4.5.2 Stress strain curve with 2% plastic strips

Table 4.10. UCS test with 4% plastic bottle strips

4% PLASTIC							
Deformation DR	**Load DR**	**Sample Deformation ΔL (mm)**	**Strain (Ɛ)**	**Strain %**	**Corrected Area (A)**	**Load (kg)**	**Stress (kg/cm2)**
25	1	0.25	0.011521	1.152074	19.91062	0.2196	0.0110293
57	2	0.57	0.026267	2.626728	19.62452	0.4392	0.0223802
85	3	0.85	0.039171	3.917051	19.38084	0.6588	0.0339923
112	4	1.12	0.051613	5.16129	19.15153	0.8784	0.0458658
156	5	1.56	0.071889	7.18894	18.78925	1.098	0.0584377
184	8	1.84	0.084793	8.479263	18.56576	1.7568	0.0946258
210	10	2.1	0.096774	9.677419	18.36294	2.196	0.1195887
243	14	2.43	0.111982	11.19816	18.11181	3.0744	0.1697456
276	18	2.76	0.127189	12.71889	17.86746	3.9528	0.221229
305	23	3.05	0.140553	14.0553	17.6581	5.0508	0.286033
335	26	3.35	0.154378	15.43779	17.44663	5.7096	0.327261
362	30	3.62	0.16682	16.68203	17.26058	6.588	0.3816788
387	32	3.87	0.178341	17.8341	17.09183	7.0272	0.4111439

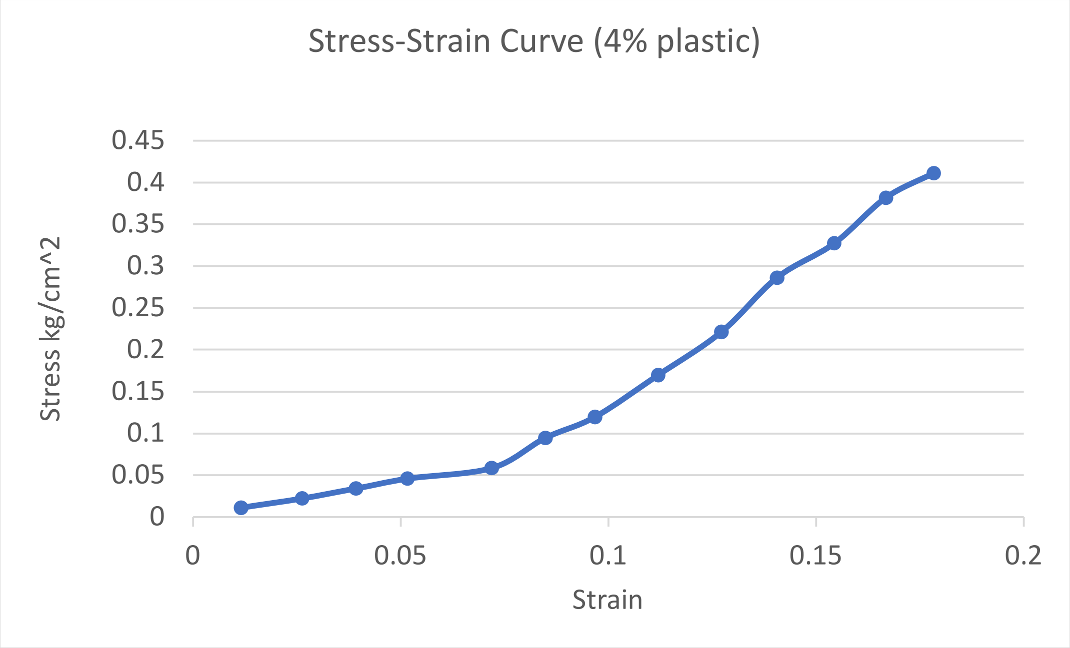


Figure 4.5.3 Stress strain curve with 4% plastic bottle strips

Table 4.11.UCS test with 8% plastic bottles strips

8% PLASTIC							
Deformation DR	**Load DR**	**Sample Deformation ΔL (mm)**	**Strain (Ɛ)**	**Strain %**	**Corrected Area (A)**	**Load (kg)**	**Stress (kg/cm2)**
22	1	0.22	0.010138	1.013825	19.93786	0.2196	0.0110142
56	2	0.56	0.025806	2.580645	19.63333	0.4392	0.0223701
86	4	0.86	0.039631	3.963134	19.37225	0.8784	0.0453432
113	5	1.13	0.052074	5.207373	19.14314	1.098	0.0573573
135	7	1.35	0.062212	6.221198	18.96043	1.5372	0.0810741
160	8	1.6	0.073733	7.373272	18.757	1.7568	0.0936611
168	10	1.68	0.077419	7.741935	18.69281	2.196	0.1174783
172	12	1.72	0.079263	7.926267	18.66089	2.6352	0.1412151
198	14	1.98	0.091244	9.124424	18.456	3.0744	0.16658
218	19	2.18	0.100461	10.04608	18.30142	4.1724	0.2279823
225	20	2.25	0.103687	10.36866	18.24793	4.392	0.2406848
270	26	2.7	0.124424	12.4424	17.91139	5.7096	0.3187692
275	28	2.75	0.126728	12.67281	17.87476	6.1488	0.3439933
285	29	2.85	0.131336	13.13364	17.80196	6.3684	0.357736

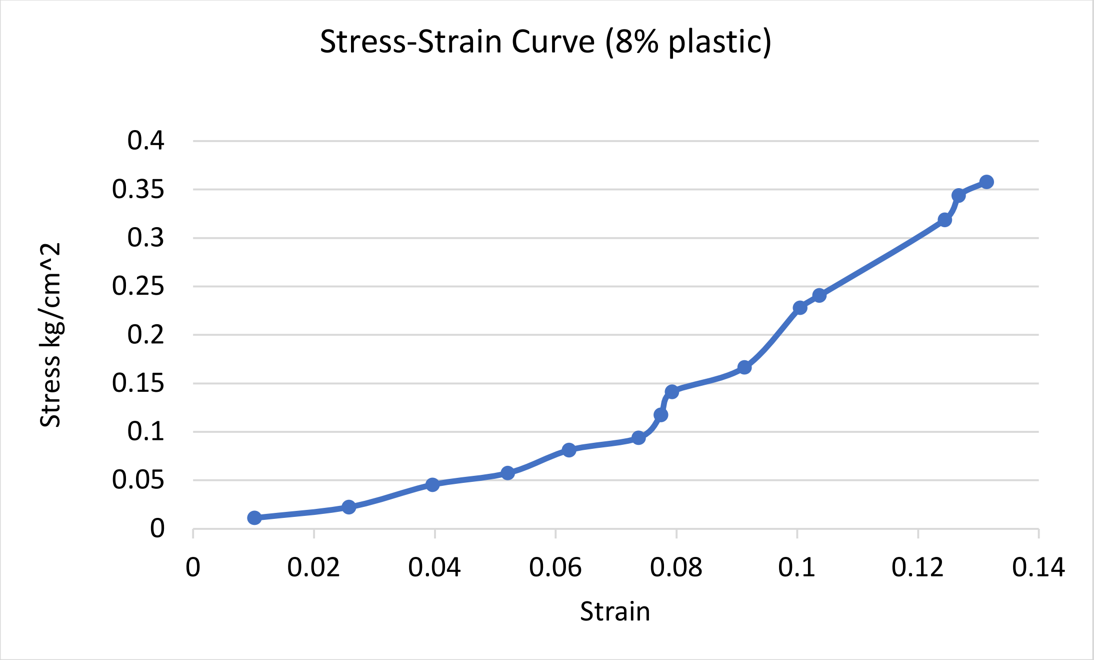


Figure 4.5 4 Stress strain curve with 8% plastic bottle strips

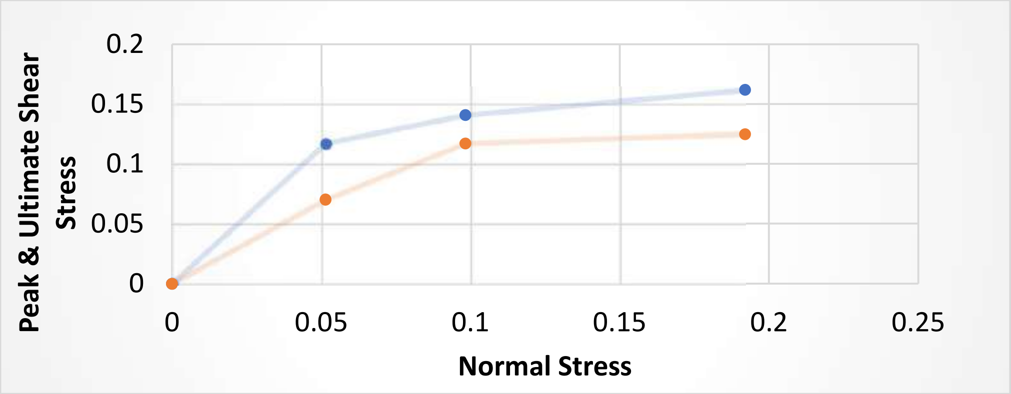
ANNEXURE B4

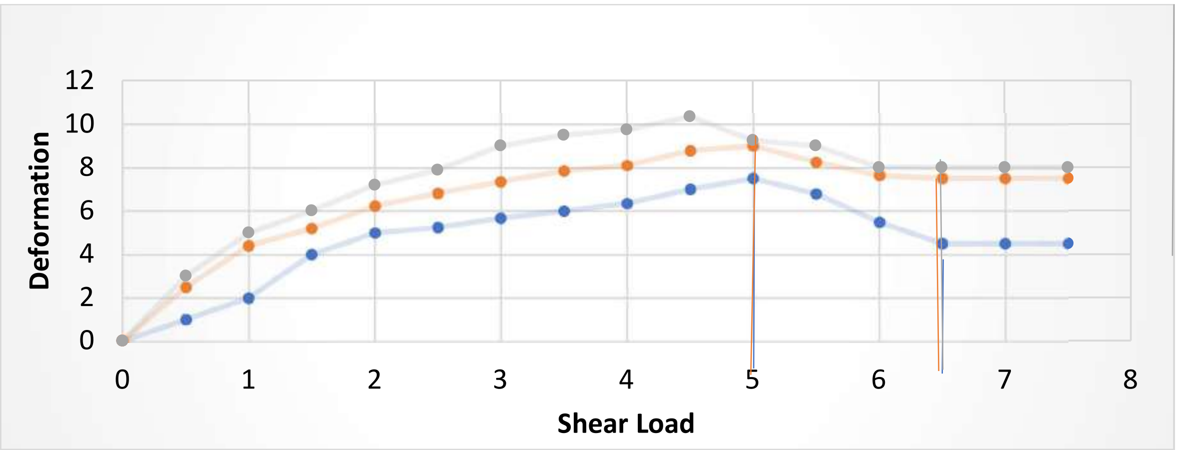
Direct shear test

With soil only

Lateral Deformation (mm)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)
	3.29	6.29	12.29
0	0	0	0
0.5	1	2.5	3
1	2	4.4	5
1.5	4	5.2	6
2	5	6.23	7.2
2.5	5.25	6.82	7.9
3	5.67	7.35	9
3.5	6	7.85	9.5
4	6.35	8.1	9.75
4.5	7	8.78	10.35
5	7.5	9	9.25
5.5	6.8	8.25	9
6	5.5	7.65	8
6.5	4.5	7.5	8
7	4.5	7.5	8
7.5	4.5	7.5	8

Normal Stress (kg/cm2	Peak Shear Stress (kg/cm2)	Ultimate Shear Stress (kg/cm2)
0	0	0
0.05140625	0.1171875	0.0703125
0.09828125	0.140625	0.1171875
0.19203125	0.16171875	0.125

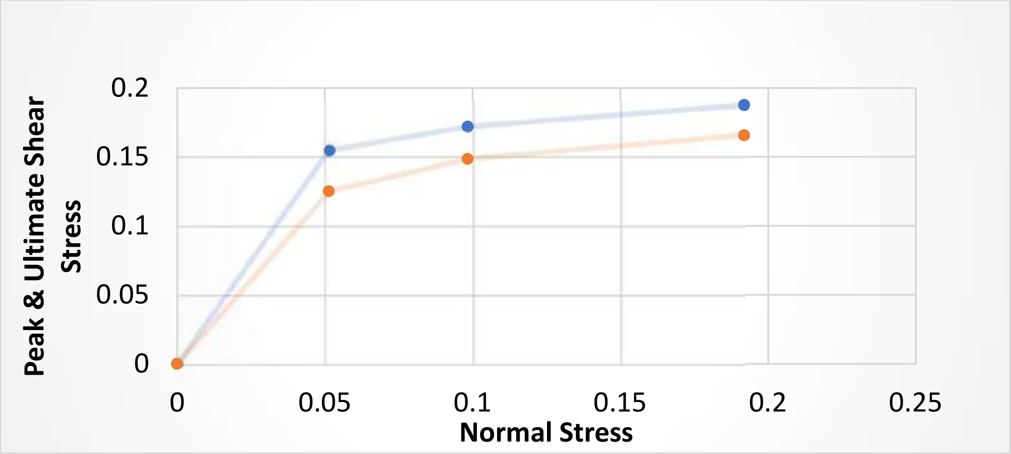


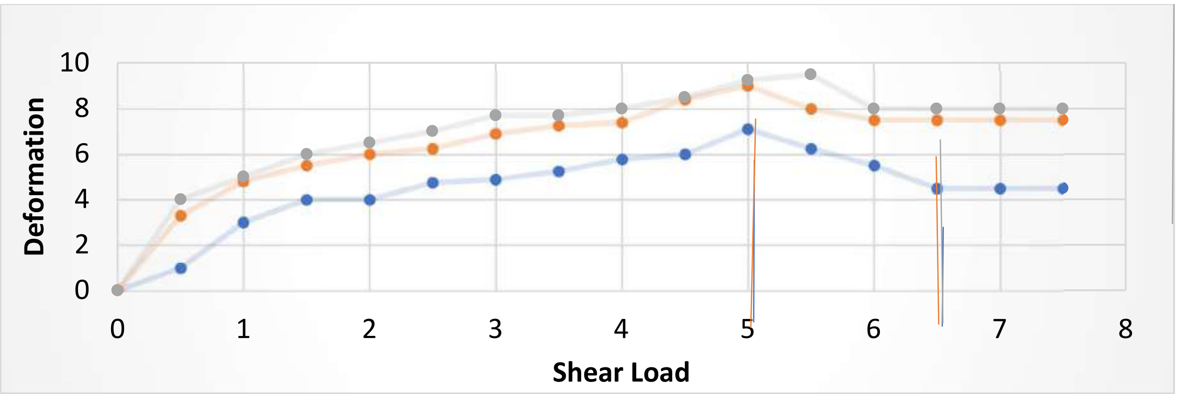


With 2% plastic

Lateral Deformation (mm)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)
	3.29	6.29	12.29
0	0	0	0
0.5	2	3	3.5
1	4	4.5	5.25
1.5	5	6	6
2	7	6.45	7.5
2.5	7.3	6.9	8.3
3	7.9	7.35	9.4
3.5	8.2	8.2	10.75
4	8.5	8.7	11.6
4.5	9.2	9.3	12
5	9.9	10.25	11
5.5	9	11	11.35
6	8.4	10	10.9
6.5	8	9.5	10.6
7	8	9.5	10.6
7.5	8	9.5	10.6

Normal Stress (kg/cm2	Peak Shear Stress (kg/cm2)	Ultimate Shear Stress (kg/cm2)
0	0	0
0.05140625	0.1546875	0.125
0.09828125	0.171875	0.1484375
0.19203125	0.1875	0.165625

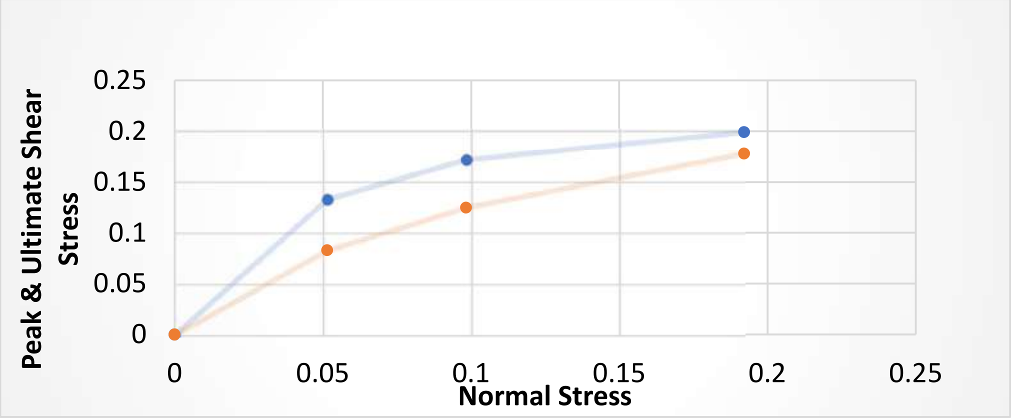


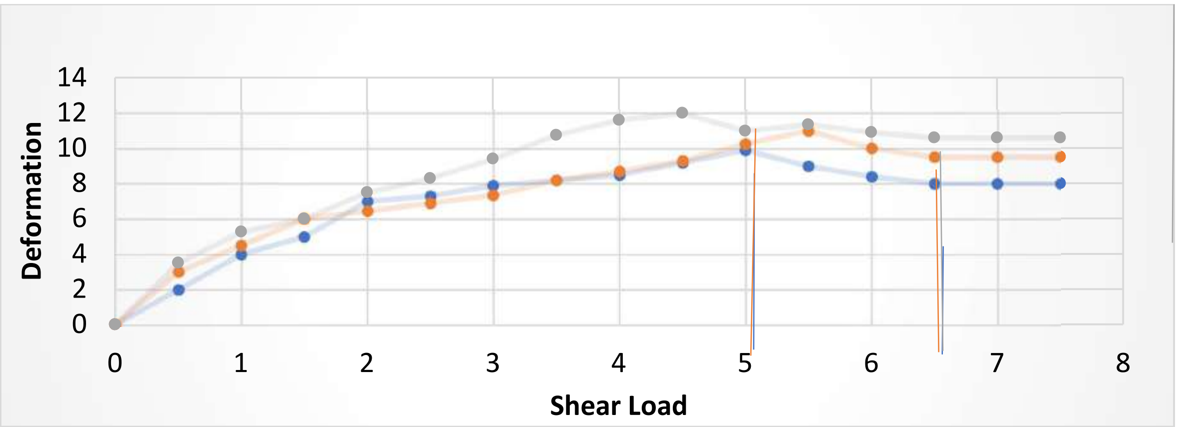


With 4% plastic

Lateral Deformation (mm)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)
	3.29	6.29	12.29
0	0	0	0
0.5	1.5	2	3.25
1	2.7	4.5	4.5
1.5	4.3	5.8	5.75
2	5.5	7	6.35
2.5	6.25	7.9	7.8
3	6.9	8.5	8.4
3.5	7.8	9.3	9.65
4	8.2	10.25	10.9
4.5	8.5	11	11.7
5	7.5	10.75	12.75
5.5	6.8	9.7	12.35
6	6.2	8.6	11.45
6.5	5.3	8	11.45
7	5.3	8	11.45
7.5	5.3	8	11.45

Normal Stress (kg/cm2	Peak Shear Stress (kg/cm2)	Ultimate Shear Stress (kg/cm2)
0	0	0
0.05140625	0.1328125	0.0828125
0.09828125	0.171875	0.125
0.19203125	0.19921875	0.178125





With 8% plastic

Lateral Deformation (mm)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)	Shear Load (kg) at normal load= (kg)
	3.29	6.29	12.29
0	0	0	0
0.5	1	2.5	3
1	2	4.4	5
1.5	4	5.2	6
2	5	6.23	7.2

2.5	5.25	6.82	7.9
3	5.67	7.35	9
3.5	6	7.85	9.5
4	6.35	8.1	9.75
4.5	7	8.78	10.35
5	7.5	9	9.25
5.5	6.8	8.25	9
6	5.5	7.65	8
6.5	4.5	7.5	8
7	4.5	7.5	8
7.5	4.5	7.5	8

Normal Stress (kg/cm2	Peak Shear Stress (kg/cm2)	Ultimate Shear Stress (kg/cm2)
0	0	0
0.05140625	0.1171875	0.0703125
0.09828125	0.140625	0.1171875
0.19203125	0.16171875	0.125