1.3.2

Sample Reports of Project Work/ Field Work / Internship

Greater Noida Institute of Technology (Engg. Institute)

Plot No. 7, Knowledge Park II, Greater Noida
Uttar Pradesh 201310 India

USING WASTE AND POLYMER FOR SOIL STABILIZATION

A Project Report Submitted
In Partial Fulfillment of the Requirements
For the of the Degree of

BACHELOR'S OF TECHNOLOGY
In
CIVIL ENGINEERING
by:-

ALIYAS ALI (1813200003)
FAIZAN AHMAD (1813200007)
MD AFTAB (1813200013)
SHRISTI SINGH YADAV (1813200033)

Under the Supervision of

MS. TARANPREET KAUR
(Assistant Professor,GNIOT)

DEPARTMENT OF CIVIL ENGINEERING

GREATER NOIDA INSTITUTE OF TECHNOLOGY,
GREATER NOIDA

Affiliated to Dr. A.P.J.Abdul Kalam Technical University,Lucknow,
(Formerly Uttar Pradesh Technical University,Lucknow,U.P)

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GREATER NOIDA INSTITUTE OF TECHNOLOGY

PLOT NO. 7,K.P. II, GREATER NOIDA,UP-201310

Affiliated to Dr.A.P.J.Abdul Kalam Technical University,Lucknow,UP

(Formerly known as Uttar Pradesh Technical University, Lucknow)

CERTIFICATE

This is to certify that the project work entitled **"STUDY USING WASTE AND POLYMER FOR SOIL STABILIZATION"**carried out by **SHRISTI SINGH YADAV , MD AFTAB ,FAIZAN AHMAD and ALIYAS ALI** , are bonafide students of "Greater noida institute of technology" , In Partial fulfillment for the award of the "Degree of Bachelor ofTechnology". Prescribed by APJ Abdul Kalam technical university,Lucknow during the academic year 2019-2022. It is certified that all the suggestions indicated for internal assessment have been incorporated in the report deposited in the departmental library. The project report has been approved as it certifies the academic requirements in respect of project work prescribed for the said degree.

(Ms. TARANPREET KAUR)
Guide

(Dr. R.K SHARMA)
Prof. & Head

(Mr. SAURAV YADAV)
Coordinator

DECLARATION

We hereby declare that this submission is our own work and that, to the best of our knowledge and belief. It contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of the university or other institute of higher learning, except where due acknowledgment has been made in the text.

Aliyas Ali
Roll no: 1813200003
Date: 01/06/2022

Md Aftab
Roll no: 1813200013
Date: 01/06/2022

Faizan Ahmad
Roll no: 1813200007
Date:01/06/2022

Shristi Singh Yadav
Roll no: 1813200033
Date: 01/06/2022

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ABSTRACT

Soil is an important part in distributing load from superstructure present over it. Soil provides firm support to the structure, if the stability of the soil is not adequate then failure of structure occurs in form of settlement, cracks etc. Black cotton soil is more responsible for such situations and this is due to the presence of montmorillonite mineral in it, which has the ability to undergo large swelling and shrinkage. To overcome this, properties of soil must be improved by artificial means known as 'Soil Stabilization'. It is a technique which improvises one or more soil properties by mechanical, cementing and chemical use. With 70% of the Indian population surviving on farms, Western Maharashtra is popular for production of sugar cane. Sugar factories produce a large amount of waste after extraction of sugar cane in machines that waste when burnt, the resultant ash is known as 'Bagasse Ash'. It is a fibrous material and can be used to improve the existing properties of black cotton soil. In this study laboratory experiments were conducted on black cotton soil with partial replacement by Bagasse Ash (3%, 6%, 9% and 12%). This project highlights significant increase in properties of black cotton soil obtained at 6% replacement of Bagasse Ash.

Keywords: Clay Soil, Plastic Strips, Soil Stabilization, CBR Test.

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CHAPTER - 1

INTRODUCTION

1.1.SOIL STABILIZATION:-

Soil Stabilization is the biological, chemical or mechanical modification of soil engineering properties. In civil engineering, soil stabilization is a technique to refine and improve the engineering properties of soils. These properties include mechanical strength, permeability, compressibility, durability and plasticity.

[Figure 1.1 Method of soil stabilization, Source : Google]

1.2. Types of soil stabilization: -

1.2.1.Cement Soil Stabilization

Soil can be stabilized by mixing it with cement. The cement contains active ingredients that help in disintegration of soil particles. Besides that, the cement helps in concealing the soil. Other materials added into the mixture include lime, calcium chloride, sodium carbonate, sodium
sulfate and fly ash. The amount of cement that's added into the mixture varies depending on the type of soil that's being stabilized.
The recommended amount is 10% on gravel, 12% for sandy soils, 15% for silts and 20% for clay soil. This is because each type of soil has a unique composition and structure.

1.2.2.Lime Soil Stabilization

Lime is ideal for stabilizing clay soils. In fact you can use it as the only agent and get perfect results. When lime is blended with any type of soil, it helps in cutting back on its plasticity. This means that it can't swell and can't shrink. Such soil absorbs very little amount of ground water because there is no space between the particles. You can actually drive a car on such a surface without the risk of getting stuck. This is due to the fact that the soil can't stretch as you would expect with other types of soils that are not stabilized.

1.2.3. Bitumen Soil Stabilization

During the construction of driveways and parking yards, the soil can be mixed with bitumen compounds. The bitumen is sticky by nature and it therefore helps in holding the soil particles together. The structure of bitumen creates a strong layer above the soil that prevents groundwater from being absorbed.

1.2.4.Chemical Soil Stabilization

Just like the name suggests, this method involves adding chemicals into the soil. These chemicals react with the soil which in return causes its structure to be changed. The chemicals seal the space between particles, leaving no room for water to penetrate through. Among the most common chemicals that are used for soil stabilization include sodium chloride, calcium chloride and sodium silicate Other chemical that are added into the soil include polymers, chrome lignin, alkyl chlorosilanes, siliconates, amines and quaternary ammonium salts.

1.2.5.Polymer Stabilization

Polymer soil stabilization refers to the addition of polymers to improve the physical & engineering properties of soils (Polymer Soil Stabilization, 2019). Polymers tend to increase the strength of the soil through their interaction with clayey particles present in the soil. Many polymers currently used, tend to increase the water retention capability and the shear strength of the soil. Polymers used for soil stabilization can be classified into two main categories viz. Biopolymers and Synthetic Polymers. Biopolymers are eco-friendly as compared to other chemical soil stabilizers.

1.2.6.Other Methods

You can also stabilize your soil using electricity. The process is known as electroosmosis and is highly recommended for clay soils. However, the method will give you a run for your money because it's damn expensive. You can also package soil in plastic and fabric sacks. Although this approach is cumbersome, it helps in compacting the soil and breaking it into smaller particles. The method is ideal for roads that are not yet paved.

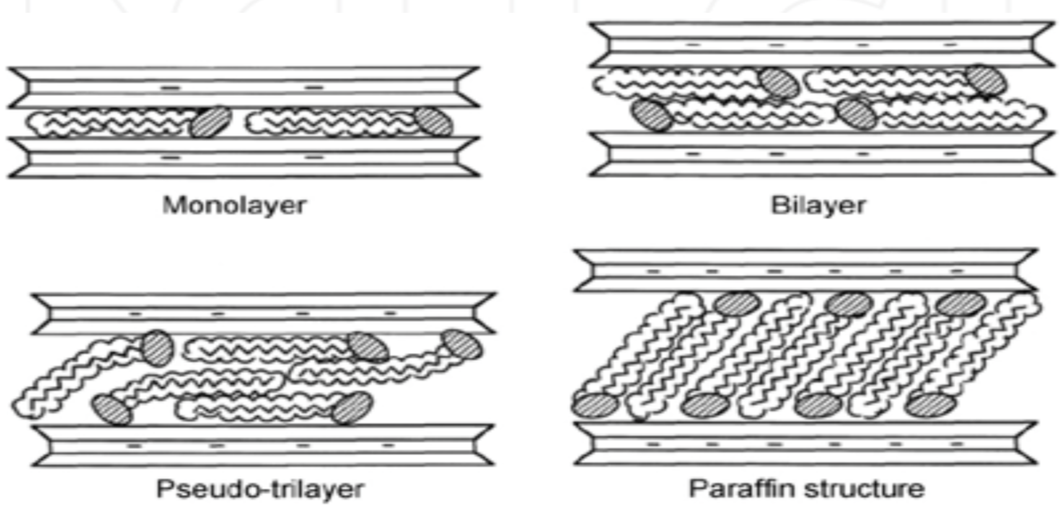
1.2. Polymer soil stabilization

Refers to the addition of polymers to improve the physical properties of soils, most often for geotechnical engineering, construction, or agricultural projects . Soil is one of the most commonly encountered materials in civil engineering.

All the structures except some, which are founded on solid rock, rest ultimately on soil. Geotechnical engineers all over the world face huge issues when structures are found on soil which is expansive in nature. This expansiveness is imparted to such soils when they contain clay minerals like montmorillonite, illite, kaolinite etc. in considerable amounts. Due to the clay minerals, the swelling soils expand on wetting and are subjected to shrinkage on drying. These soils are commonly unsaturated. The problem of instability of structures made on such soil is mainly due to lifting up of the structures on heaving of

soil mass under the foundation on saturation during rainy season and settlement as a result of shrinkage during summer season. Due to this cavity formed, leading to loss of contact between the soil and structures at some points. This successively results in splitting of structure and failure due to loss of shear strength or unequal settlement.
Foundation is a very important part of any civil engineering construction work. Load of any structure is ultimately taken by foundation; hence it is very necessary to prepare a sufficient strong base for any structure. Bottom most portion of the structure consists of a natural earth surface, this earth surface is known as soil. For successful transfer of load of structure on the soil it is necessary to prepare soil with desirable bearing capacity, also it is not possible every time to get soil having sufficient strength at every place. Process of increasing the strength of soil by artificial processes is known as stabilization of soil.

The process of soil stabilization refers to changing the physical properties of soil in order to improve its strength, durability, or other qualities. Soil stabilization is important for road construction, and other concerns related to the building and maintenance of infrastructure. Stabilization of soil is carried out by adding lime, coconut coir, fly ash, plastic fiber etc. with the soil. Investigation into the properties of SoilTech and DustTech treated expansive soils would assess the suitability of using SoilTech and DustTech as stabilizers to reduce swelling of expansive soils.



[Figure 1.2 Polymers stabilize soil through interactions , Source:Google]

This review study presents the effect of polymers on soil stabilization on engineering properties of expansive soil. There are two types of Polymers as discussed below SoilTech Mk. III is a third generation Nano polymer binder used for stabilizing soils for improving the strength of the soil and thereby improving the stability Even at very small concentrations within soils, various polymers have been shown to increase water A wide range of polymers have been used to

address problems ranging from the prevention of desertification to the reinforcement of roadbeds retention and reduce erosion, increase soil shear strength, and support soil structure . Polymers that have been tested for soil stabilization effects include a range of synthetic polymers and biopolymers. Biopolymers in particular offer a more eco-friendly alternative to traditional chemical additives, such as ordinary cement, which may generate a large amount of carbon dioxide during production or cause lasting environmental damage. Polymers mainly affect the aggregation and strength of soils through their interactions with fine clay particles. Coatings of adsorbed polymers on clays can increase their steric stabilization by preventing clay particles from approaching each other as closely. Alternatively, polymer molecules that bond with multiple clay particles promote flocculation.

Hydrogel networks can result in more indirect strengthening within soils by creating a scaffolding for soil particles. Additional strength can be imparted to polymer networks within soils through chemical cross-linking and curing. Synthetic polymers began replacing other chemical binders for soil stabilization in agriculture in the late 20th century. Compared to traditional chemical binders, polymer soil additives can achieve the same amount of strengthening at much lower concentrations –

For example, mixtures of 0.5-1% of various biopolymers have strength levels that match or exceed those of 10% cement mixtures in soils.] Synthetic polymers, including geopolymers, and biopolymers have been tested for their beneficial interactions with soils. Methods for introducing polymers into soils include mixing, injection, spraying, and grouting.

Liquid polymers, sold as concentrated solutions, can be applied deep within the soil through pressure injection or applied directly to uncompacted soil. DustTech is a water based polymer emulsion which is sticky to touch apparent odor; totally nonflammable.

It is a combination of various water based copolymers including ethylene glycol, polyvinyl acetate, polyvinyl alcohol stabilizer and colanyl pigment for coloring. DustTech is totally miscible with water and will be progressively diluted if admitted to the waterway.

The base polymer is slowly biodegraded. DustTech is nonflammable, not hazardous, nontoxic, and environmentally free.

1.3. Problem Related To Soil

Problems occurring with existing soils are those which are encountered by geotechnical engineers. They are considered as a high natural hazard, which can cause extensive damage to structures such as foundations, roads, highways, building, airport runways and earth dams if not adequately treated. Damage caused by expansive soils exceeds the combined average annual damage from floods, cyclones and earthquakes. Some remedial measures can be taken to prevent the damages. These are exchanging the soil under the foundation with the other soil, controlled

compaction of expansive soil, moisturizing, structure of moisture barriers, lime stabilization and cement stabilization, modification of the structure and lowering the foundations from upper layer to the lower level.

1.4. Remedial Measures for Above Discussed Problem

Soil Stabilization is the process of making something physically more secure or stable. Soil stabilization is the process of blending and mixing material with a soil to improve certain properties of the soil. The process may include the blending of soils to achieve a desired gradation or the mixing of additives that change the properties of soil.

1.5. Classification of Soil Stabilization Techniques Soil stabilizations are classified on the method of stabilization.

1.5.1 Mechanical stabilization -

The old method of stabilization is mechanical in nature. Mechanical methods involve physically changing the property of the soil, in order to affect its grade, proportion, and other characteristics. Portable compaction is one of the major types of soil stabilization; in this procedure a heavy weight is put repeatedly onto the ground at regular intervals.

Vibrating compaction is another useful technique that works on similar principles; it removes voids between the soil particles by vibrator.

1.5.2 Chemical stabilization -

Chemical methods are the methods which use chemicals to increase the strength of soil. Chemicals are used to change the proportion of soil particles. All of these techniques rely on adding an additional material to the soil that will physically interact with it and change its properties. There are a number of different chemicals that utilize cement, lime, fly ash, and kiln dust for soil improvement.

1.5.3 Soil Stabilization by using Polymer -

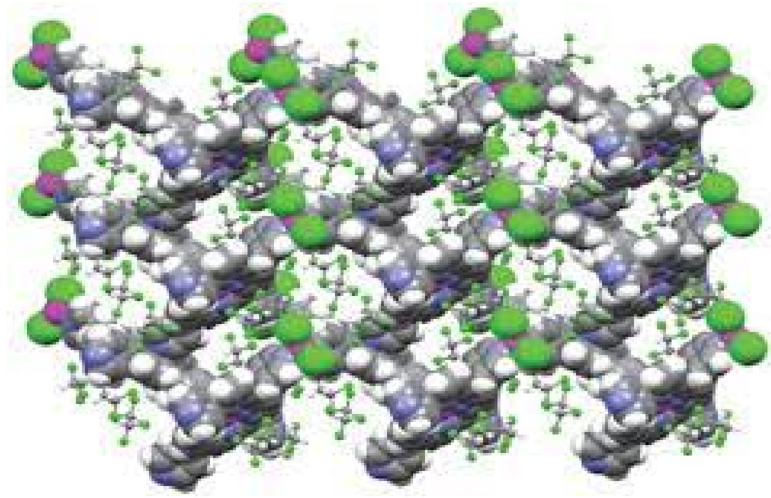
Researchers invent some innovative techniques for soil stabilization like using polymer, and polypropylene etc. These new polymers and substances have a number of important benefits over traditional mechanical and chemical solutions; they are economic and more effective in general than mechanical methods, and significantly less dangerous for the environment than many chemicals tend tobe.

1.6. POLYMER

1.6.1 SoilTech Polymer -

It is a stabilization agent and was specifically designed & developed for mine haul road stabilization, where excessive loading occurs and where all-weather roads are required. This technology is now used in commercial road design. SoilTech Mk. III stabilizing polymers are elastomers, which gain strength from mechanical compaction and do not become brittle when cured. The elastomers are flexible in nature and allow a certain amount of flex under load and do not become brittle unlike cement stabilization, will not crack under excessive loading – one aspect in reducing layer work in design phases. In most cases, the in-situ soils in the area can be used for stabilization.

The SoilTech Polymers are the forefront of binding marginal soils and turning these materials into usable road construction aggregate. SoilTech Mk. III has been extensively tested with in-situ materials in various parts of the world. SoilTech Mk. III has been extensively utilized in base and sub-base stabilization using in-situ materials, throughout the developing world.



[Figure 1.3 SoilTech Mk. III stabilizing polymers, Source:Google]

1.6.2 Benefits of SoilTech Polymer -

Reduce the consumption of quarry aggregate in road and thereby minimize the significant environmental impact. In situ material can be used. Reduced road crust speed up to construction time Reduce construction cost. Reduce maintenance . Increase the strength and stability of the base subbase layer .

1.6.3 Advantage of dust tech Control dust –

keep livable things healthy. Open road to traffic immediately after applying DustTech, Stabiles dust and sand road and prevent them becoming slippery when wet, Improve productivity through better road, Cost effective, Environmentally friendly and skid proof when wet, Easy application, Long life strength, Non- flammable .

1.6.4 Problem with many dust tech polymer alternatives -

Water can be an effective short term solution but when the moisture dries it leaves the soil more fragile creating even more dust. Oil base emulsion continuously percolates and leaches through the soil, never binding with the road bed particle to stabilize the surface .

1.7. Plastics

Plastics are resins or polymers that have been synthesized from petroleum or natural gas derivatives . The term 'plastics' encompasses a wide variety of resins each offering unique properties and functions. In addition, the properties of each resin can be modified by additives . Different combinations of resins and additives have allowed the creation of a wide range of products meeting a wide variety of specifications . Polymers are chemically inert large molecules made up of repeating chemical units (monomers) that bind together to form long chains or polymers . Polymers are pure materials formed by the process of polymerisation, though cannot be used on their own, but additives are added to form plastics . These additives include: antistatic agents, coupling agents, fillers, flame retardants, lubricants, pigments, plasticisers, reinforcements, and stabilizers (Harper 2006). Pure polymers may include silk, bitumen, wool, shellac, leather, rubber, wood, cotton and cellulose Stellenbosch University , argues that plastic production and use has grown because of the many advantages plastics offer over other more traditional materials.

A few of the desirable intrinsic properties of plastics include :

i) Design flexibility – plastics can be modified for a wide variety of end uses,

ii) High resistance to corrosion,

iii) Low weight, and

iv) Shatter resistance.

1.7.1. Types of Plastic:-

1.7.2.Common Plastic- This category includes both commodity plastics, and engineering plastics. Some examples are-

a-polyamides

b-polycarbonate

c-polyvinyl chloride

d-polyester

e-polyvinylidene chloride

f-polyethylene- it includes packing bags and plastic bottles.

1)high density polyethylene

2) Low density polyethylene

3) polyethylene terephthalate

1.7.3. Special plastic- polyepoxide phenol formaldehyde urea formaldehyde polyamide .

1.7.4. Type of plastic used in this study :

In this study strips of plastic bottles are used. Plastic bottles come under the Polyethylene terephthalate group. Some properties of polyethylene terephthalate are :

I. It is hard, strong and dimensionally stable material.

II. It absorbs very little water.

III. It can be transparent and colorless but thick sections are opaque and off white.

1.8. Plastic Industry

Plastic production is a major part of the chemical industry and most of the world's biggest chemical companies have been involved from the very beginning, like BASF and DOW. These companies came from eighteen countries with more than two third of the companies having headquarters in the United States. Mostly these plastic manufacturing companies were located in just three countries: United States(12) Japan(8) ,Germany(6). From India export of plastic products stood at US$ 8.85 billion in 2017(source : plastics export promotion council) and it gives employment to about 4 million people .The Indian plastic industry produces and exports a wide range of raw materials, polyester films ,polyvinyl chloride ,soft luggage item, luggage clothes and sheetings ,sanitary fittings ,tarpaulin, electrical accessories and others. Among the industry's major strengths the availability of raw materials in the country is its biggest. According to a report, consumption of plastic in India will cross 20 million tonnes by 2020. This indicates that the Indian plastic industry is growing at a very high rate with a plastic consumption rate of 16% per year. Despite having a population of 125 crore plastic companies are reporting a shortage of labor.

This shortage of labor has led to investment in modern technology like conveyor belts etc. Along with shortage of labor, India is also facing a power deficit of around 15%. In

India various fields have a share in the plastic consumption. Some of these are electronics industry, packaging industry, transportation industry, agriculture etc.

1.9.1. Plastic waste generation in India

1) In India around 25,940 tonnes of plastic waste is generated in a day (t/day), according to a report made by the Central Pollution Control Board (CPCB) that studied 60 major cities.
2) These cities together produced 4059 T/day.
3) Delhi takes first position in generating maximum plastic waste followed by Chennai,Mumbai, Banglore and Hyderabad.

1.9.2. Applications of plastic in civil engineering field

Plastic has numerous applications in different sectors like: construction, packaging, automotive, furniture, sports, electrical and electronics, health and safety, consumer and household appliances. In the civil engineering field, plastic is used as components in the construction of bridges, buildings, roads and highways, ports and terminals, railroads, landscaping, landfills, water retaining structures, etc . The plastic components that are used in the construction industry include: sound barriers, guide rails/guard rails, piles, piers, railroad ties, pallets, curbs/wheel stops, bulk heads, docks, board walks and walkways, bicycle racks, foundation backfills, erosion control, and construction materials separations. In civil engineering for a material to qualify as a good construction material it should be durable, strong, ductile, easy to install, fire resistant, and inexpensive. the characteristics of plastic compared with other construction materials, and since this research focused on reinforced soil with Polyethylene Terephthalate (PET) plastic waste.

The following are the qualities of construction plastics:
i) Plastics are strong, and can resist knocking and scratching.
ii) Plastics are durable, making them withstand harsh weather.
iii) Plastics are easy to install and move around.
iv) Plastics offer design freedom in that it can be turned into any shape, and plastic products can be coloured, opaque, or transparent, rigid or flexible.

v) Plastics promote energy efficiency in buildings since they are low conductors of heat, and can achieve a tight seal.

vi) Plastic products have low maintenance cost and do not need painting.

vii) Plastic building products can be recycled with low energy input and can as well be turned into energy.

viii) Constructing using plastic products is cost effective since plastic is durable, of good quality, has low maintenance cost and saves labor.

1.9.3. Management of plastic wastes

"Solid waste management refers to all activities pertaining to the control of generation, storage, collection, transfer and transport, treatment and processing, and disposal of solid wastes in accordance with the best principles of public health, economics, engineering, conservation, aesthetic, and other environmental considerations" . Waste is an item (plastic, food, paper, and etcetera) rejected for being of no use or value to the owner after its intended application. classify waste as follows:

i) Physical state (like solid, liquid and gaseous)

ii) Origin (like agriculture, mining, quarrying, manufacturing, industrial, construction, household, commercial, etcetera)

iii) Physical properties (combustible, compostable, and recyclable)

iv) Safety level (like hazardous, and non-hazardous)

v) Material type (like plastic, glass, metal, paper, food, etcetera)

vi) Usage (like packaging waste, food waste, etcetera)

All wastes excluding liquid and gasses are termed as solid waste. Commercial solid wastes and household solid wastes together form the municipal solid waste (MSW). The MSW include plastics, organic, metals, papers, glass. MSW are usually mixed together, hence it is laborious to manage while disposing of. Solid waste management is the process of safely disposing of MSW through recycling, incineration, and landfill to avert polluting humans and the environment. For this section of the chapter, attention is geared towards plastic waste management. Most of the post-consumer plastic waste is landfilled along with municipal solid waste . Plastic waste accounts for a large and growing portion of the municipal solid waste stream (EPA 1990). Plastics are about 7% (by weight) of municipal solid waste and a large percentage by volume estimated to be in the range of 14 to 21 percent of the waste stream . Considering the trend, this amount of plastic waste is predicted to increase. The composition of the USMSW stream of 250 million tons generated in the year 2010. Source Management of plastics in a landfill Plastics are non-degradable and do not affect the structural integrity of a landfill. However, plastic wastes do affect the landfill capacity due to their large numbers and continued plastics production. Management of plastics in an incinerator Plastics contribute significantly to the heating value of municipal solid waste, with a heating value of three times that of typical municipal waste . Controversy exists regarding whether halogenated plastics (e.g. polyvinyl chloride) contribute to emission from municipal waste incinerators . Analysis should be done for the emission of toxic acid gasses. investigation should be done on lead and cadmium (plastic additives) as they may contain heavy metals leading to toxicity of incinerator ash .Therefore, waste management teams should plan on how to eliminate the entire waste stream before it degrades the environment. Source reduction processes are as follows :

i) Modifying design of product or package to decrease the amount of material used,

ii) Utilizing economies of scale with large size packages,

iii) Utilizing economies of scale with product concentrates,

iv) Making materials more durable so that it may be reused, and

v) Substitute away from toxic constituents in products and packaging.

1.9.4. Recycling

Recycling is the process of converting waste materials into reusable products, and it is important to say that plastic recycling is in its infancy stage. Despite the seven SPI plastic identifications , most of the recycling companies or individuals concentrate on PET and HDPE plastic waste . These plastic wastes make only 5% of the postconsumer plastic waste stream and the rest is either incinerated or put in landfill or abandoned in open space.explains below the single homogeneous resins or a mixture of plastic resins recycling technologies:

1) Recycling PET and HDPE plastic waste is an example of homogenous resin, which yields products similar in quality to those of virgin resins. PET and HDPE plastic waste

can be recycled over and over again, hence reducing the need for PET and HDPE disposal.

2) Considering plastic identification according to SPI , in this case plastic wastes can be mixed and recycled into new low cost construction building materials which can compete with wood and concrete . In this case, the recycling process becomes simple as sorting of different types of plastic waste . However, these recycled products can't be recycled again as in the previous scenario. Therefore, this process may delay the ultimate disposal of these plastic waste through recycling once but not over and over again .

Factors limiting recycling:-

1) Collection and supply: one of the limiting factors of recycling is the collection and supply of single resins or a mixture of resins . The single resins are affected most due to the complex composition of plastic wastes. As in most cases plastic wastes consist of a variety of different types of plastic types. Collection of plastic waste can be done by "bottle container deposit, road curbside collection, drop off centers, and buy-back centers" .

2) Markets: PET and HDPE plastic waste recycled products market is available on a large scale . Though, it should be noted that markets for mixed plastic waste recycled products are hard to get and the production of such products is still at its infancy .

1.10. Polyethylene Terephthalate (PET)

Manufacture of PET Polyethylene Terephthalate (PET or PETE), is a strong, stiff synthetic fiber and resin. PET is a member of the polyester family of polymers. PET is produced by the polymerisation of ethylene glycol and terephthalic acid. Ethylene glycol is a colorless liquid and a product of ethylene, and terephthalic acid is a crystalline solid which is a product of xylene. Once ethylene glycol and terephthalic acid are heated together under the influence of chemical catalysts, it results in a molten viscous PET.

This molten PET can be turned into fibers directly, or solidified in order to be processed into plastic at a later stage . Chemically, ethylene glycol is a diol, an alcohol with a molecular structure that contains two hydroxyl (OH) groups .

Terephthalic acid is a dicarboxylic aromatic acid with a molecular structure that contains a large six-sided carbon or aromatic ring and two carboxyl (CO2H) groups . Under the influence of heat and catalysts, the hydroxyl and carboxyl groups react to form ester (CO-O) groups, chemical links joining multiple PET units together into long-chain polymers. Water is also produced as a by-product.

1.10.1. General uses and properties of PET

Polyethylene Terephthalate (PET) is usually stiff and strong, which makes it applicable in various sectors. PET can be made into high-strength textile fibers, which are used in durable-press blends with other fibers like rayon, wool, and cotton; reinforcing the inherent properties of those fibers while restraining them from wrinkling.Also PET can be used in the manufacture of fiber filling for insulated clothing; and for furniture and pillows. Artificial silk and carpets are also made from small and large PET filament fibers respectively. Furthermore, PET can be used in automobile tyre yarns, conveyor belts and drive belts, reinforcement for fire and garden hoses, seat belts .

Also PET can be used in the manufacture of geotextiles for stabilizing drainage ditches, culverts, and railroad beds. Also diaper top sheets and disposable medical garments, magnetic recording tapes and photographic films, liquid and gas containers, water and beverage bottles.

1.10.2. Effects Of Plastic On Environment

As plastic is non decomposable material or has a very slow rate of decomposition so it will accumulate in the environment and adversely affect the ecosystem. Plastic which acts as pollutants are divided into two types according to their sizes. These are micro and macro pollutants. As plastics are economical and durable than other materials, their production by humans is quite high. The chemical structure of plastic makes them resistant to many natural processes of decomposition as a result they are almost non decomposable material. These above two factors have created plastic pollution. Some harmful effects of plastic are noted below.

1) When plastic bags are left in the soil, they slowly release toxic compounds which ultimately reach the ground water table. If any living being drinks this water it will cause severe health issues.

2) It leads to the loss of wildlife. Many animals after eating plastic suffer from severe health problems. Any animal who has eaten plastic suffers from obstruction in intestines which leads to a quite long and painful death. Some animals die after eating plastic because as plastic decomposes very slowly it makes the animal full which ultimately leads to death due to malnutrition.

3) Clogging of the sewage system by plastic bags mostly in urban areas causes severe harm to the environment. This clogging of the sewer causes inconveniences to the people living or working in that area. The excess water rises due to clogging can cause harm to buildings and properties. It will also collect the pollutants from the area and spread them as far as it flows which is an extra problem associated with it.

4) It also deteriots the natural beauty. It ruins the aesthetic appearance of every ecosystem. Plastic waste disposed into the ocean releases toxic chemicals which will sometimes lead to extinction of some aquatic species.

1.10.3. Regulations And Legislations For Plastic Waste In India

1) The Ministry of Environment has established a nationwide plastic waste management task force which has encouraged a strategy and action programme for managing plastic waste in India.

2) BIS(Bureau of Indian standards) has issued some guidelines on plastic waste recycling which includes code of practice for collecting the plastic waste, upgradation of the technique of sorting the waste plastic etc. The Ministry of Environment in association with BIS (bureau of Indian standards) also carried out some practice for the reuse of recycled plastic waste whenever appropriate.

3) The prevention of food adulteration department of the government of india has issued directives to food caterers to use only food grade plastic while serving the food. Rules have specified the food grade plastic which has certain requirements and is safe when in contact with the food.

4) PET manufacturers have formed a national association of PET which will look at organized collection and recycling of PET bottles.

1.11. Fiber-Reinforced soil

Due to rapid urbanization worldwide and increased rural-urban migration, coupled with an increase in the world population estimated to be 7 billion people, there has been an increase in the creation of cities to accommodate for the demand of houses and better infrastructures. This has led to, shortage of quality building materials and suitable sites with proper soil properties for proposed buildings and any other civil engineering projects. In civil engineering a site for a project, say for a building, or any other civil engineering construction project is key in the project‟s existence. This determines whether the project will be able to be established on that site or not. The first step in the determination of the suitability of the site for any construction or civil engineering project is to carry out a site investigation. This helps in determining the properties of the soil and water level, history of the site, and the existing services available on or near the site.

1.12. Statement of problem

The cost of stabilizing and improving expansive soils with conventional methods such as mechanical compaction, use of admixtures, injection of suitable grouts, etc. is becoming more expensive than ever . With the scarcity of selected material for construction and the surplus amount of weak and poor quality expansive soil discarded from construction with limited space for dumping the weak soil, stabilizing soils with PET plastics comes in handy in road subgrade, embankment fill, and in building construction. Plastic and materials made with plastic have become an integral part of our day to day life in various stages and also in various forms , but then, the disposal and dumping of the used and unwanted plastic has become a major threat for the civilized society , as the production and usage of new plastic and plastic associated materials are not in balance with its recycling and recycled plastic products status. When plastic is disposed of by burning into the open air, it easily spoils and pollutes the air, land and water body nearby. When plastic is dumped in landfills, it does not break up or decay fast and as a result, it interacts with water and forms hazardous chemicals . Meanwhile, in Ethiopia, there are many plastic manufacturers producing different categories of products from tires to plastic floor tiles. Among these factories, plastic bottle manufacturers for water packaging are growing fast. In the country, it is forbidden by law to manufacture plastics less than 0.3 milligrams by weight . The average production capacity of a plastic bottling factory is 30,000 bottles per hour, making the total bottle production in the country very high annually .

The production is growing year by year with the introduction of new factories and all of these bottles are not recycled properly and end at the landfills and incinerators .Previous works suggest the addition of plastics in soils not only improve the compressibility of the soil but also increases the load bearing capacity of sandy soil in road construction . This research uses clay type soils instead of sandy soils. In this study, the waste products from plastic bottle materials (polyethylene Terephthalate fibers) were managed to be recycled and modified as synthetic reinforcement fibers for soils. The usage of these plastic strips is reasonable, cost-effective and constantly available

1.13. Significance of the study

With the rising cost of industrial stabilizing chemicals (agents) and costly mechanical methods of stabilizing conduct for expansive soils, it is becoming very expensive to manage and conduct construction works which require improvement of existing soils on site . Also Due to improper application of industrial stabilization agents to minimize 4 construction costs, accidents and disasters happen during and after construction all over the world including Ethiopia. Tunnel landslide, slope failure, rutting in roads and cracks in buildings occur mostly due to poor application of stabilization on expansive and collapsible type soils To tackle these kinds of construction problems using affordable and simply available material such as plastics is a very good alternative. One of the considerations to meet these is to transform these plastic wastes into items applicable for development, construction, and housing .

Over the last few years there has been a considerable rise in the use of plastic products which caused a proportionate increase in the plastic waste. But only a lesser quantity of such materials are recycled and reused and rest of them are stored or thrown to the disposal. These plastic materials are used in lesser quantities for engineering purposes. Several studies have shown that the addition of plastic waste in soil will cause a development in the strength characteristics of soil.

1.14. Scope and limitations

A suitable clayey (expansive) soil and PET plastic bottle strips were basic elements to conduct the study. A bulk sample of black cotton soil was taken from a privately owned construction site in the city of Addis Ababa, Ayertena, area. The bulk sample was dug out at a depth of 0.5 meters within a one-meter square area. Disturbed sample of soil was taken to the laboratory for a further sampling of appropriate amount and size in order to conduct the necessary experiments. PET plastics used for water packaging purposes were selected for the experiments specifically. They were collected from the local market near Ayertena and were limited to half liter water holding capacity and are from one brand in order to minimize the change in the character of the PET plastics. Atterbergs soil consistency tests using Casagrande apparatus and Standard Proctor Compaction tests to determine the maximum dry density and the optimum moisture content of the specimen were conducted.

CHAPTER - 2
LITERATURE REVIEW

2.1 GENERAL

Following literature was studied related to soil stabilization using polymers. This unit contains a review of soil stabilization using polymers.

Sanjay J. Shah (Nov-2002), "Stabilization of fuel oil contaminated soil - a case study" Fuel oil pollution brings unfriendly effect on essential geophysical properties of establishment soil. The present study relates to one such case, from the petrochemical complex close to Vadodara City in Gujarat State, India. In this study, fuel oil pollution brought on injurious impacts to the fundamental geotechnical properties of the CL sort of soils. Oil tainted soil when warmed with various adjustment specialists like lime, fly slag and concrete either freely or as an admixture demonstrated a change in the geotechnical properties. This change can be credited to scattering of oil, cation trade, agglomeration, and pozzolanic activities of added substances to specific lime, fly powder and concrete. Best results were watched when soil was treated with a blend of 10% lime, 5% concrete and 5% fly slag. During the time spent adjustment fuel oil may have shaped a steady complex with metals. Increment in the quality of the soil can be ascribed to transformation of mixes like CSH, CSH-1, that coat and scaffold soil grains.

Reliance private ltd. (2010) companies make the evaluation report of SoilTech treated soil stabilized base layer. The company is about construction for the power generation, for the installation of machineries or tower. is on the constructed base layer which is stabilized by SoilTech polymer. The company makes a case study on it and all results are carried out on the basis of various tests done by sudhakar reddy from IIT Kharagpur. Result is very positive and shows that SoilTech is a good industrial construction soil stabilizer.

Rabindra Kumar et al.; (2012),"Plate load test on fiber-reinforced cohesive soils" This report talks about the heap settlement reaction from three plate load tests (0.3m × 0.3m square 25 mm profound) did on a thick homogeneous stratum of compacted strong soil, strengthened with haphazardly dispersed polypropylene filaments and coir strands, and additionally on the same soil without the support. The plate load test on the soil fiber layer was performed to generally heavy weights, and yielded an observable stiffer reaction as compared to the unreinforced stratum. A definitive burden for the unreinforced soil is observed to be 42 KN and the qualities for soil strengthened with coir filaments and polypropylene strands are 70 KN and 80 KN individually.

Along these lines, a definitive heap of the dirt fortified with 0.8% coir filaments and 0.5% polypropylene strands increments by 67% and 90% separately when contrasted with unreinforced soil. Fiber strengthened soil is fit for retaining more strain vitality preceding disappointment. Therefore, soil-fiber network might be utilized as an enhanced material as a part of the field of geotechnical building.

Miss Apurva J Chavan (Apr-2013), "Use of plastic waste in flexible pavements." Transfer of waste materials, including waste plastic packs has turned into a grave inconvenience and waste plastics curve smoldered for obvious transfer which causes natural pollution. Utilization of waste plastic sacks in bituminous blends has demonstrated that these improve the properties of blends notwithstanding taking care of transfer issues. Plastic waste which is cleaned is cut into a size such that it blurs through 2-3mm sifter utilizing the destroying machine. The total blend is warmed and the plastic is successfully covered over by biting the dust total.

This plastic waste covered total is blended with hot bitumen and they came about to utilize lot street development. The utilization of the imaginative innovation won't just fortify the street development additionally build the street life and will enhance the earth, Plastic streets would be a shelter for India's hot and to a great degree sticky atmosphere, where temperatures regularly cross 50°C and exuberant downpours make ruin, leaving the majority of the streets with huge potholes.

Chander Bhal Roy (Mar-2013), “Stabilization of soil of bidian origin.” Scrap tires are being created and gathered in substantial volumes bringing about an expanding risk to the earth, keeping in mind the end goal to kill the negative impact of these testimonies and in terms of reasonable advancement there is extraordinary enthusiasm for the reusing of these nonhazardous strong squanders. The capability of utilizing elastic from worn tires as a part of numerous structural designing works have been contemplated for over 20 years, Tire squanders can be utilized light weight material either as a part of the type of powder, chips,destroyed and in general. Utilizations of tire elastic turned out to be compelling in securing the earth and monitoring normal assets. They are utilized above and subterranean water. Numerous work with respect to the utilization of scrap tires in geotechnical application have been done particularly as bank materials (Ghani et al, 2002) The reuse application for tire is the means by which the tire are handling essentially incorporates destroying, expelling of metal fortifying and further destroying until the wanted materials are accomplished A traveler auto tire contains around 26% carbon dark. 47% normal elastic, 30% of manufactured elastic, India is creating one lakh metric ton of reuse elastic which is sold @ Rs 70 for each Kg.

R. N. Nibudey et al.; (Feb-2013), "Strength Prediction of plastic fiber reinforced concrete (M30)." Nowadays we are confronting environmental security issues. Many things which are planned for our sumptuous life are in charge of contaminating the environment because of the uncalled for waste administration method. One of them is a plastic which holds lo be disposed of or reused appropriately to save the excellence of our temperament. To address this issue the strands from utilized plastics were included as a part of different parts in the M30 grade concrete. This paper distinguishes the execution of plastic fiber fortified cement (M30). A test study has been taken out on the examples like 3D shapes and barrels which were thrown in the research center and their conduct under the test was watched. The plastic strands were added from 0.0 % to 3.0 %. The compressive and split resistances of cement were found following 28 days curing period.

VaishaliSahu (Dec-2013), "Sustainable reuse of stabilized and fiber reinforced fly ash-lime sludge (FALS) as pavement sub-base material." In the road construction sector, the world is confronting a noteworthy issue of shortage of traditional building materials. Then again, in that appreciation are numerous twist offs from different fabricates, which are lying as waste. In the present study, a composite material made up of fly fiery remains

and lime slime (FALS) was attempted as sub-base material in the clearing. Adjustment of FALLS with industrially accessible lime and gypsum was done and the impact of adding polypropylene strands to balanced out FALS was examined. A progression of unconfined pressure tests was done on examples of fiber-strengthened fly fiery debris lime muck composite (FRFALS) to evaluate the impact of fiber consideration on the sturdiness and flexibility attributes of the composite. The result of fiber support on the shear strength parameters and California Bearing Ratio (CBR attachment (c) and inside rubbing point (ϕ) is additionally discussed. Taking into account the outcomes, it has been contemplated that the expansion of low measures of polypropylene fiber (0.1 %) expands the solidness and malleability of the FRFALS for the distinctive curing time frame.
The CBR estimation of FALSE expanded by 54% with fiber expansion and the shear parameters c and ϕ likewise increments. Henceforth the FALS composite is appropriate in sub-base layers of adaptable asphalt, in the event that it is strengthened with polypropylene fiber.

Asokan Pappu (2013) , “Solid waste generation in India and their recycling potential in building materials.”."To shield the earth, endeavors are being made for reusing particular misuses and utilizing them in worthy applications. In this paper, present status on generation and usage of both non-hazardous and dangerous solid waste in India, their reusing possibilities and natural ramifications are accounted for and talked about in points of interest in the public arena to augment the use of option building materials produced for various instances of strong squanders and expand the yield limit of lab scale forms, innovation empowering focuses are requested that be set-up to encourage business visionaries for viable commercialization. Toughness and execution of the more up to date items and open introduction of innovations, stressing money saving advantages investigations and life cycle evaluation report will essentially prompt effective commercialization of modem operations. The crisp and option building development materials created utilizing agro modern squanders have adequate extension for bringing out new development components that will weaken to a degree the costs of development fabrics. The endeavor, in this way, should be to support business people and development organizations to develop novel items and operations utilizing every one of these squanders as crude materials for setting up auxiliary commercial ventures and adding to the diminishment of nursery gasses and worldwide recuperating.

J.Ranjitha et.al (2013), studies on experimental study on black cotton soil stabilized using SoilTech MK 3 polymer. This paper investigated how pavement construction is becoming costlier because of the very high cost of construction materials and transportation cost of such materials from long distances. The growing concern over environmental degradation due to borrowing of large quantities of soil and aggregates for construction of pavement has made the search for new techniques of stabilization. The subgrade soil should have high Maximum dry density (MDD) and low Optimum moisture content (OMC) so that it can take up the load of the overlying layers and the traffic. The high MDD and corresponding OMC can be achieved by stabilizing the soil using a suitable stabilizer. In the present work the effect of using Nano Polymer called SoilTech MK III as a stabilizer to improve the properties of Black Cotton soil collected from Karnataka, India were determined. The laboratory experiments were conducted on the samples of BC soil and BC soil with stabilizer for Compaction test, UCS (Unconfined Compression Strength) and CBR (California Bearing Ratio) tests. Various samples were prepared by taking soil with different percentages of SoilTech MK III Polymer (0.2%, 0.4%, 0.6%, 0.8% and 1.0%). The comparison of the results with and without the use of SoilTech MK III has been done. Expansive clay soils are types of soils that show a significant change in volume once they come in contact with moisture. They expand when exposed to excess water and shrink in hot weather conditions where there is a scarce amount of water. They can easily be identified in the field in dry seasons as they show deep cracks of polygonal patterns. This behavior of swelling and shrinking of expansive clay soils in turn affects the stability of structures that are built over these soils causing a serious hazard.

G. S. Hambirrao et al.(Feb-2014), “Soil stabilization using waste Shredded rubber `tyre chips.” Development of designing structures on frail or delicate soil is considered as perilous. Change of load bearing capacity of the ground might be shrunk by an assortment of ground improvement techniques. In the present examination, destroyed elastic from waste has been taken as the support material and concrete as restricting operator which was arbitrarily incorporated into the soil at three distinct segments of fiber substance, i.e. 5% 10% and 15% by weight of soil. The test has been concentrated along the quality conduct of soil fortified with arbitrarily included destroyed elastic lire. The specimens were subjected to California bearing ratio and unconfined compressive strengths tests. The trials have obviously exhibited a significant development in the shear strength and bearing capacity parameters of the concentrated on soil.

IJTARME(Jan-2014) "Study on heavy characteristics of black cotton soils using copper slag with cement as admixture." Black cotton soil is one of the significant nearby soil deposits in India, spreading over a field of about 3.0 lakh sq.km. black cotton soils are enormously far from being obviously true, as they swell on ingestion of water and therapist on vanishing thereof, as an after-effect of this substitute swell and shrinkage; distress is made to the bases of structures laid on such grounds. Copper slag, which is created amid hydrometallurgical generation of copper from copper minerals, contains materials like iron, aluminum oxide, calcium oxide, silica, and so on. For each metric ton of metal creation, around 2.2 tons of slags are produced.
Dumping and transfer of such unfathomable measures of slag causes ecological and space problems. Therefore, we apply the modern waste - Copper Slag to decrease the swelling of far reaching grounds. The present paper clarifies about the works being done utilizing copper slag as a padding material. Advancements of strong bonds in a concrete balanced out copper slag pad, when settled with bond, are required to result in capture hurl. The results of the study show a novel answer for the issue hurl of expansive soil.
It additionally determines the issue of copper slag mi Hellion and transfer to some extent.
D. N.

Vijaya Kumar et al; (Jan-2014), "Evaluation of wear properties of industrial waste (Slag) reinforced polypropylene composites." A decent arrangement of waste is delivered by commercial ventures and they are stacked up on soil which makes state and natural issues. Government approaches and controls constrain us to search for decisions. In this manner, scientists are endeavoring to use these squanders as in composites. Slag is a mechanical waste fortified in polypropylene composites. The stick-on plate wear testing machine has been used to look at the grinding and wear behavior of the polymer composites. The wear adversity and coefficient of disintegration are plotted against the ordinary loads and sliding rates. It is noted from the graphical representation of the outcome that with the expansion in burden weight reduction declines and increment in sliding speed weight reduction likewise increments.

Malhotra Akshat and Ghasemain Hadi [2014] studied the effect of high density polyethylene(HDPE) plastic waste on the Unconfined Compressive Strength of soil. In a proportion of 1.5%, 3%, 4.5% and 6% of the weight of dry soil HDPE plastic waste is added to the soil. They concluded that the Unconfined compressive strength of black cotton soil increases on the addition of plastic waste. When 4.5% plastic waste mixed with the soil, strength obtained was 287.32KN/m2 which is maximum as the strength of natural soil was 71.35KN/m2 .

Nagle Rajkumar et al [2014] performed CBR for improving engineering performance of sub grade soil. They mixed polyethylene, bottles, food packaging and shopping bags etc as reinforcement with black cotton soil, yellow soil and sandy soil. Their study showed that MDD and CBR value increases with increase in plastic waste. Load bearing capacity and settlement characteristics of reinforced soil were also improved.

Chebet et al [2014] did laboratory investigations to determine the increase in shear strength and bearing capacity of locally available sand due to random mixing of strips of HDPE (high density polyethylene) material from plastic shopping bags. A visual inspection of the plastic material after tests and analysis indicates that the increased strength for the reinforced soil is due to tensile stresses mobilized in the reinforcements. The factors identified to have an influence on the efficiency of reinforcement material were the plastic properties (concentration, length, width of the strips) and the soil properties (gradation, particle size, shape).

Jaypal et al. [2014] discussed the comparison of different admixtures using weak soil stabilization. In this paper, admixtures such as quarry dust, fly ash and lime were compared. The tests such as liquid limit, plastic limit, modified proctor compaction, sieve analysis, differential free swell and CBR were conducted. He concluded that the addition of quarry dust, lime and fly ash had not prevented the swelling nature. He also concluded that there was an increase in the CBR value with the partial replacement of 20% quarry dust which in turn reduced the pavement thickness of road construction.

Baraskar Tushal et al. [2014] had studied CBR of Black cotton soil. He partially replaced the soil with waste copper slag in various percentages. He conducted various tests such as grain sieve analysis, compaction characteristics and CBR. He concluded that the maximum CBR value is obtained in black cotton soil with 28% replacement of copper slag. He also concluded that such soils can be effectively used as the sub base layer of road pavement.

Karthik et al. [2014] had studied soil stabilization by partially replacing red soil with Fly Ash. He conducted various tests such as CBR, specific gravity, MDD with OMC, UCC, liquid limit and plastic limit. He finally concluded that 9% partial replacement of fly ash in the soil results in improved properties and he also said that those soils showed good bearing capacity.

Mishra Brajesh et al. [2014] had investigated the engineering behavior of black cotton soil and its stabilization by use of lime. The tests were conducted for properties like atterberg limit, CBR value, free swell index and compaction factor. He finally concluded that 5% partial replacement of soil with lime is optimum to stabilize the black cotton soil. He concluded that 5% partial replacement of fly-ash resulted in reduced liquid limit (15.27%) and swelling and it also increased the CBR values.

Anjaneyappa et.al (2015) studies character action of polymer stabilization. The construction of pavements is becoming costlier due to the very high cost of quality construction materials and transportation cost from long distances. Highway engineers are forced to look for ways to reduce the cost of construction and sustainable construction

materials and methods. Soil stabilization techniques are important in constructing economical and sustainable roads. Nontraditional stabilizer additives are being marketed as cost effective, environmentally friendly potential solutions by manufacturers for stabilization of pavement layers with very high claims . Various types of nontraditional stabilizers available in the market include chemical, polymer, enzyme based stabilizers.
Conclusion made by this paper was reduction of about 41 to 47% in radial strains below bituminous layers and 38 to 47 % in vertical compressive strain on subgrade were observed for soil stabilized with polymer. Similarly reduction in thickness of granular layers in the order of about 50% was observed. It is necessary to study the field performance using the polymer stabilizer for both low and high volume roads. The use of polymer for stabilization pavement layers can be considered for low volume roads.

Dhatrak A.I. et al [2015] after reviewing the performance of plastic waste mixed soil as a geotechnical material it was observed that for the construction of flexible pavement, the quality of sub grade soil of pavement gets improved using waste plastic bottles chips as an alternative method . In his paper a series of experiments are done on soil mixed with different percentages of plastic (0.5%, 1%, 1.5%, 2%, 2.5%) to calculate CBR. On the basis of an experiment that he conducted using plastic waste strips he concluded that waste plastic strips will improve the soil strength and can be used as a subgrade. It is an economical and eco-friendly method to dispose of waste plastic because there is scarcity of good quality soil for embankments and fills.

Mishra R. S. et al [2015] had studied about the stabilization of black cotton soil by use of Fly ash, Ferric chloride and Stone dust. The soil samples were tested for liquid limit, plastic limit, OMC with maximum dry density and CBR. He concluded that the liquid limit, plastic limit, maximum dry density and CBR values are increased due to the adding of Ferric chloride 2.5%, fly ash 15% and stone dust 25%. The results indicated the improvement in soil properties and reduction in pavement thickness on road construction.

Mohammed et al. [2015] had investigated the improvement in soil properties of Expansive soil by using copper slag. The soil properties like Grain size analysis, liquid limit, plastic limit, plasticity index, compaction test, direct shear test and CBR were determined. He concluded that copper slag 40% and Black cotton soil 60% was optimum and it showed the increase in value of specific gravity and CBR. He finally concluded that such soil can be effectively used in road embankment subbase and subgrade.

Athulya P.V. et.al (2015) studies stabilization of sub grade soil using additives – a case study. The objective of the present study is to conduct experimental study and analyze the strength properties of plain soil, soil with terrasil and soil with cement kiln dust separately by conducting consistency limit test, CBR test, Triaxial test and permeability test and then to compare the effectiveness of these additives on stabilizing the weak soil Conclusion made by this paper the behavior of soil varies largely with introduction of stabilizer. It is observed that increment in doses resulted in decrement of consistency limits. So it is clear that the chemical makes the soil stiff. It is noted that CBR value increases with increase in dosage of stabilizer and an optimum value is obtained. Cement kiln dust being a waste product is economical and the CBR value also showed a considerable increase. The water proofing property of soil had a significant effect of adding Terrasil compared to cement kiln dust. The elastic modulus value for soil with additives showed a considerable increase compared to unsterilized soil.

Bibha mahtr et.al (2015) studies a review paper on improvement of subgrade by rbi grade 81 and pond ash The objective of the study is to find out the impact of RBI Grade 81 at 2%,3% and 4% mixed along with pond ash 3%, 6% and 9% on silty and clayey soil and the change in California Bearing Ratio (CBR), Dynamic cone penetration (DCP) Maximum Dry Density (MDD), Optimum Moisture Content (OMC) has been observed through different mixes of RBI Grade 81 and pond ash on soils. The outcome helps in looking at the change in CBR, DCPT, OMC, MDD value when soils were stabilized by RBI grade 81 and soils stabilized by both RBI Grade 81 and Pond ash. Conclusion made by this paper is the RBI Grade 81 is successful in adjustment of most sorts of soils. The increment in CBR esteem fluctuates w.r.t sort of soil.

For some soils, the augmentation is substantial with little expansion of the chemicals like fly ash, Sodium Silicate, pond ash, morum and stone dust. Since RBI Grade 81 assistance to use by regional standards accessible soil for road construction, consequently the expense of construction can be diminished by maintaining a strategic distance from substitution of soil. The splashed CBR qualities increment with expansion in RBI 81 expansion recommend its suitability as great stabilizer to enhance execution of delicate soils. The utilization of fly ash alongside RBI Grade 81 essentially enhances the geotechnical properties of soil.

Fauzi Achmad et al [2016] calculated the engineering properties by mixing waste plastic High Density Polyethylene (HDPE) and waste crushed glass as reinforcement for subgrade improvement. The chemical element was investigated by Integrated Electron Microscope and Energy-Dispersive XRay Spectroscopy (SEM-EDS). The engineering properties Plasticity index, Cohesion, Optimum moisture content values were decreased and friction angle, Maximum dry density, CBR values were increased when content of waste HDPE and Glass were increased.

Michael Tiza et al [2016] had reviewed the stabilization of soil using industrial solid wastes. In his paper, he studied the replacement of different materials such as Red mud, copper slag, brick dust, polyvinyl waste, ceramic dust, sawdust and fly ash. The soil samples were tested by Atterberg limits, CBR and compaction test. He had concluded that almost all the industrial wastes have the ability to enhance the properties of enhancing the properties of expansive soil with less cost.

Ravi et al .[2016] had studied the characteristics of clay soil by using copper slag stabilization. In this paper, he tested the CBR and Max density, OMD relationship. He observed higher CBR values in 30% replacement of copper slag and this also served as good conformity for the flexible pavement with simultaneous reduction in the sub base course thickness. He finally concluded that the addition of 30% copper slag with 70% BC soil was the suitable stabilization ratio which increased all characteristics of sub grade requirements.

Summaya et al. [2016] had studied soil stabilization using tile waste. In this paper, tests were conducted on UCC, CBR, liquid limit, plastic limit, compaction test and shrinkage limit. She concluded that there was reduction in value of liquid limit, plastic limit and

OMC and increase in the value of shrinkage limit, MDD, UCC, CBR in addition to tile waste up to 30%.

Paliwal et al. [2016] had experimentally studied the stabilization of sub grade soil by using foundry sand waste. In this paper he tested various properties like liquid limit, plastic limit, plasticity index, Standard proctor test, CBR and Direct shear test. He concluded that the CBR value and angle of internal friction of soil was improved with addition of 20% foundry dust. He also concluded that OMC shows a lower value for 10% replacement of foundry waste.

Butt Ali et al. [2016] had investigated the strength behavior of clayey soil stabilized with sawdust ash. The soil properties were determined by computing the Liquid limit, plastic limit, plasticity index, specific gravity, UCS and CBR. He observed that the property of soil showed an acceptable value up to 4% replacement of sawdust ash. He had discovered that sawdust ash acceptably acted as a cheap stabilizing material for road pavement.

Michael Tiza et al. [2016] had reviewed the stabilization using industrial solid wastes. In this paper, he studied the replacement of different materials such as Red mud, copper slag, brick dust, polyvinyl waste, ceramic dust, sawdust and fly ash. The soil samples were tested by Atterberg limits, CBR and compaction test. He had concluded that almost all the industrial wastes have the ability to improve the expansive soil with less cost compared to conventional soil.

P.K.KOLAY, et.al (2016) studies" the effect of liquid polymer stabilizer on geotechnical properties of fine grained soil", there are Two types of soils were selected in this study i.e., Carbondale soil (clay with high plasticity (CH)) and Galatia soil (silt of low plasticity (ML)) for stabilization purpose. A copolymer liquid stabilizer has been selected for this study. Two types of Soils were selected in this study i.e., Carbondale soil (clay with high plasticity (CH)) and Galatia soil (silt of low plasticity (ML)) for stabilization purposes. A copolymer liquid stabilizer Soiltac has been selected for this study.
According to the manufacturer, the polymer used in the present study is non-toxic and non hazardous. The pH value of the polymer is 5.5. Typically, polymer stabilizers are

vinyl acetates or acrylic copolymers suspended in an emulsion by surfactants. The polymer added 0.5%, 1%, 1.5%, 3%into the both soil and various tests to occur .The result gets positive and fulfills the conclusion of this study. From the result of investigation conducted, the following conclusion can be made: The Atterberg limit for Carbondale soil (CH) and Galatia soil (ML) were slightly decreased with the addition of polymer, and no significant changes were observed for both soil. With the addition of polymer, MDD increases and OMC decreases for Carbondale soil (CH) and Galatia soil (ML). For Carbondale soil (CH), UCS values increases upto the addition of 1.5 % of polymer by weight and thereafter decreases for 3.0 % polymer addition. Also, UCS values increase with the increase in curing period for all soil-polymer mixture.

1) The maximum increase in UCS value (with 1.5 % polymer stabilizer and 28-days of curing period) was 220% with polymer. For Galatia soil (ML), no significant changes in UCS were observed for all soil polymer mixture at any curing periods.

2) Maximum increase in UCS value was approximately 23% with polymer.

3) Unsoaked CBR value for Carbondale soil (CH) increases upto 1.5% of polymer addition and then decreases with 3.0% polymer stabilizer.

4)The increases in unsoaked CBR values from untreated soil are 200% for 2.54 mm deformation and 195.5% for 5.08 mm deformation with 3-days of curing.

5)Almost similar unsoaked CBR values are obtained for 7 and 28 days of curing.

Basantadhakal et.al (2016) studies the effect of liquid acrylic polymer on geotechnical properties of fine grained soil. This paper investigates the effect of liquid polymer on the geotechnical properties of fine grained soil. Commercially available liquid polymer (acrylic polymer) was used to stabilize natural Carbondale soil (Soil A) and commercially available soil (Soil B).

1)The polymer was mixed at various percentages (i.e., 2, 3, 4, and 5 %) of the dry weight of both soils.

2)Tap water was added corresponding to its OMC (optimum moisture content) for a particular soil-polymer mixture and compacted to achieve its maximum dry unit weight.

3)The compacted samples were allowed to cure for 7, 14, and 28 days under a confined and open air environment.

4)Unconfined compressive strength (UCS) test was performed to evaluate the strength of polymer stabilized soil.
5)The results show that with the addition of polymer; UCS value for Soil B samples prepared at OMC increases from 30 to 75 % in the open air environment and the UCS value increases from 12 to 14 % in the confined air environment. Soil A samples prepared at OMC (i.e23.50%) show cracks while curing in an open air environment and there is no significant change (i.e., 1.2–13.8%) of strength in a confined air environment. For the Soil A samples prepared with reduced moisture contents (less than OMC i.e., 12.50%) and cured in an open air environment shows an increase in UCS strength from 7 to 10%. Also, California bearing ratio (CBR) test was performed for both soils and there was marginal increase (i.e., 14%) in CBR value for Soil A but a significant increase (i.e., 340%) in CBR value for Soil B.

Sameervyas et.al (2016) studies stabilization of dispersive soil by blending polymer to stabilization of dispersive soil from Udaipur 0.5 % and 1 % polyvinyl alcohol (PVA) and urea formaldehyde (UFR), 0.5% polyurethane (PU) and epoxy resin (ER) and 1 % styrene butadiene rubber latex were added to the soil sample. Mechanical analysis of polymer treated soil was done to measure the improvement in soil aggregation and atterberg's limit was tested to get information concerning cohesion properties of the soil. For mechanical analysis and Atterberg's limit test, chemicals were added to 4.75 mm and 425 micron passing soil samples, respectively.
To compare the effect of polymer with conventional soil stabilizer 1.0% of sodium aluminate, calcium aluminate and calcium hydroxide were added to the dispersive soil sample and mechanical analysis was done and index properties were evaluated. From the above result it is clear that adding polymer aggregate size of soil is increasing thus the polymer used for above study are effective in binding soil particles.
Lowering of LL, PL and PI indicate that on wetting of soil by rain water it will soften to a lesser extent thus making it more suitable for construction of road or lining of dam.

Kumar Rajendra et al. [2017] had studied about the Black cotton soil blended with copper slag and fly-ash which are added in different percentages. The soil properties like liquid limit, plastic limit, plasticity index, free swell, compaction test and CBR (unsoaked) were determined. The results indicated that the dry density, CBR values were improved and swelling was reduced due to addition of copper slag 30% and fly ash 10% (% by weight of soil) in the soil.

Babu Ramesh et al. [2017] had investigated the behavior of black cotton soil with addition of copper slag and steel slag. The soil samples are tested by compaction test, unconfined compression test and CBR. It is concluded that CBR, optimum moisture content, maximum dry density and shear strength are increased when the soil is added with 20% of copper slag and steel slag. All the studies that have been done on stabilization of soil suggest that there will be an increase in the shear and bearing strength of soil by the application of suitable admixture like cement, lime ,fly ash ,plastic waste ,bitumen etc. Along with strength, other soil properties like shrink- swell index, liquidity index, permeability etc. also gets better of the soil. But except for some admixtures ,most of them are quite expensive. So use of these admixtures are not feasible most of the time. New research on soil stabilization by waste materials like plastic, fly ash etc. are economical. So research on soil stabilization should be more focused on adding suitable admixtures which can not only enhance soil properties but can also be economical and feasible most of the time.

Sepehr Rezaeimalek1,,et.al(2017) studies on Mixing Methods Evaluation of a Styrene-Acrylic Based Liquid Polymer for Sand and Clay Stabilization in this paper ,focused on applications and provided promising results. This study focuses on the application of a low viscosity liquid polymer for shallow soil improvement. The mixing method of soil specimens treated with the liquid polymer soil stabilizer, which belongs toStyrene Acrylic family, was studied through an experimental testing program.The tested soils included poorly graded sand and sulfate rich clay. The water, liquid polymer and dry soil were mixed with different sequences to assess the effect on strength. The specimens were cured in a controlled environment for upto 35 days before being tested. It was found that the curing of the polymer stabilizer in sand and clay was time consuming and took up to a month to reach their full strength.

Larisa.chandris et.al (2017) studies expansive soil stabilization (general consideration) which is the paper that revives the phenomena of active clays from a mineralogical, mechanical and especially a geotechnical point of view. Clay soils exhibit, sometimes, a significant volume change due to the variation of water content in the mass of the soil, in response to climatic conditions and the action of vegetation. These volume changes affect the function of the constructions and foundations in contact with the soil and they represent the causes of damage, especially intense, during periods of drought. We conclude that in general, all lime treated fine grained soils exhibit decreased plasticity, improve workability and reduced volume change characteristics. We need to take into consideration the final aim of improving the strength characteristics of the soil. It should be emphasized that the properties of soil-lime mixtures are dependent on many factors such as soil type, lime type, lime percentage and curing conditions.

T.Raghavendra , et.al (2018) studies the stabilization of black cotton soil using Terrasil and Zycobond. The variation experiment specific gravity, liquid limit, plastic limit, sieve analysis, hydrometer analysis. IS light compaction, unconfined compression test, direct shear test, California bearing ratio test free swell index are conducted on the soil. Cement is used in the constant proportion of 3% of the amount of soil and the Nano chemicals terrasil and zycobond are used are 0.6kg/m3, 0.8kg/m3 , 1kg/m3 , 1.2kg/m3 of each. Chemical soil mixing with cement and an unconfined compression test is performed. soil mixed with cement and chemical with the respective proportion to the OMC calculated to the soil and mixed .Unconfined compressive strength test is performed after the curing period of 7 days ,21 days ,28 days free swell index is performed . for the same proportion of terrasil and zycobond . Terrasil is nanotechnology based water dissolvable , and appears in pale yellow color in the form of a field. From the result of the investigation conducted, the following conclusion can be made.

• Free Swell index is decreases from 30% to 27.5% with the addition of 0.6kg/m3 of Terrasil and Zycobond and decreased to 26.3%, 25%, 21.05% with the addition of 0.8kg/m3 ,1.0kg/m3 ,1.2kg/m3 when compared to 0% of Terrasil and Zycobond.

• Unconfined compressive strength is decreased when the dosage of the Nano chemicals (Terrasil and Zycobond) is increased.

• But many journals say that Unconfined compressive strength should be increased by adding cement, Terrasil and Zycobond. Further investigation needs to be done as to why the unconfined compressive strength is decreasing.

N.Sohaib el.al (2018) studies use of acrylic polymer for stabilization of clayey soil.in this studies acrylic polymer is used as a stabilizer which mixed with clayey soil for preparation of soil-acrylic polymer was mixed with chloroform to prepare the acrylic paste and the added to the soil.

The chloroform was evaporated later on. Each sample was sealed in a plastic sheet to make it airtight, and samples were then placed in an oven at 40^0C for the desired curing period. From the studies and experiment conclusion can be made: The use of non-traditional chemical agents (acrylic polymers) can significantly enhance the engineering characteristics of soft soil. The soil is reactive with acrylic solution. Optimum percentage of acrylic solution required for stabilization of the soil is 6% by weight of the soil. It can be used as a stabilizing agent in conjunction with acrylic is technically and financially feasible as it increases both the strength and durability parameters of soil. Compaction effort quickly after mixing acrylic solution is likely to yield maximum strength in the field.

1) The maximum dry density from untreated soil increases to 5.92% with addition of 6% acrylic polymers. Beyond this MDD starts decreasing.

2) Unconfined compressive strength increases from untreated soil to 57% (for 3, 7 and 14-days curing) with addition of 6% of acrylic polymer, further addition of acrylic polymer causes decrease in compressive strength.

3) In the California Bearing Ratio test, the maximum increment obtained from treated soil was 102% at 6% addition of stabilizer in comparison with untreated soil.

Qassun S Mohammad shafique, et.al (2018) studies on improvement on expansive soil using polymethacrylate polymers. In paper investigation one of the worldwide problematic soils is expansive clay accompanied by large volume change response when it is subjected to a change in the water content . A chemical method for enhancing the swelling of expansive clayey soil is provided using polymethacrylate (PMA) polymer material . The experiment programmer is conducted to estimate the effect of adding the(PMA) polymer on the properties of the prepared expansive soil. Modified clay specimens are characterized based on various experiments and soil samples prepared in various percentages (i.e. 3%, 5% 7%) by weight of dry soil. The results indicate that the induced PMA polymers within expansive soil caused decrease in liquid limit, plasticity index, free swell, and optimum moisture content and increase in plastic limit, unconfined compression test and CBR test. The result indicated that the polymers significantly overcome the problem of expansive soil .

In addition, higher UCS by 52.8% is observed by adding PMA with a percentage of 7%. Also adding the same percentage of PMA polymer caused an increase in CBR value by 72.8% .

2.2 Needs & Advantages

Soil properties vary a great deal and construction of structures depends a lot on the bearing capacity of the soil, hence, we need to stabilize the soil which makes it easier to predict the load bearing capacity of the soil and even improve the load bearing capacity. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids.

Thus, it is better to mix different types of soils together to improve the soil strength properties. It is very expensive to replace the inferior soil entirely and hence, soil stabilization is the thing to look for in these cases.

1) It improves the strength of the soil, thus, increasing the soil bearing capacity.

2) It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation.

3) It is also used to provide more stability to the soil in slopes or other such places.

4) Sometimes soil stabilization is also used to prevent soil erosion or formation of dust, which is very useful especially in dry and arid weather.

5) Stabilization is also done for soil water-proofing; this prevents water from entering into the soil and hence helps the soil from losing its strength.

6) It helps in reducing the soil volume change due to change in temperature or moisture content.
7) Stabilization improves the workability and the durability of the soil.

2.3. Scope of work

The experimental work consists of the following steps:
1. Specific gravity of soil
2. Determination of soil index properties (Atterberg Limits)
i) Liquid limit by Casagrande's apparatus
ii) Plastic limit
3. Particle size distribution by sieve analysis
4. Determination of the maximum dry density (MDD) and the corresponding optimum moisture content (OMC) of the soil by Proctor compaction test
5. Preparation of reinforced soil samples.
6. Determination of the shear strength by:
i) Direct shear test (DST)
ii) Unconfined compression test (UCS).
7.CBR Test.

2.4.Advantages of soil stabilization

If in the building stage weak soil masses are met, the common practice followed is replacing the weak soil with some other good quality soil. With the application of soil stabilization technique, the properties of the locally available soil can be upgraded and be used in an effective manner as the sub-grade soil without substituting it. The price of making the subgrade by exchanging the weak soil with a selected quality material soil is greater than the preparation of the subgrade by stabilizing the existing soil by utilizing different stabilization mechanisms. The strength yielding factors of the soil can be fully increased to a desired value by stabilization. It improves the strength of the soil, thus, increasing the soil bearing capacity. It is more economical both in terms of cost and energy to increase the bearing capacity of the soil rather than going for deep foundation or raft foundation . Engineering Soil stabilization basically targets to upgrade the quality of weak soil. Strength of soils is dependent on many variables such as soil particle size, moisture content, soil type and etc. treating soils with additives can be good or bad depending on the purpose of the soil.

From an engineering perspective, treated soils have good strength if the treatment is done carefully. Soils treated with stabilizers show greater strength when compared to non stabilized or untreated soils. Therefore, many fruitful applications can be conducted in this setting; foundation thickness can be reduced, placement of concrete or blacktop onto the soil can be done directly, using for sub-base is possible, cost of material like bitumen can be saved. The time to prepare sites in traditional mechanisms like 'dig and dump' can be reduced if stabilization of soils is done on the site. Because replacement of existing soils takes longer time in conventional methods. It also allows moist soils to be dry and tied up in time. Hence, these stabilization methods enhance the construction period and shorten completion time for projects. As mentioned earlier, a little amount of capital will be used since treated soils with stabilizers does not need landfill payment, dump truck and heavy 23 machinery movement, purchasing of selected material for backfilling and the like in comparison to 'dig and dump' method . Finally, it is ecology and environment-friendly. Impact rising from dump trucks transporting heavy loads can also be minimized which in turn may contribute to mitigate the global warming phenomenon.

Last but not least, Stabilization of soils is also used to grant greater stability to the soil in inclined surfaces or other such places. Sometimes soil stabilization is also used to forbid soil wearing or establishment of dust, which is very practicable especially in dry and arid weather. Stabilization is also applied for soil water-proofing; this prevents moisture from getting into the soil and therefore assists the soil from losing its strength. It aids in decreasing the soil volume variation due to change in temperature or water content .

2.5. Economic benefit of PET soil stabilization

Recent studies have shown that soil stabilization using PP and LDPE plastics is cost effective when compared with conventional methods of soil stabilizations like cement and lime additive stabilizations. In countries like the USA, Japan and European countries, cost benefit analysis is conducted where the international laws and conventions as well as regulations are available and applicable. Research and experience show that the major reductions in cost is where the replacement of cement and other chemical portions with plastic shows great change in cost. To stabilize one cubic meter of soil, the mix proportions for cement and lime can be 25 to 35 percent of the total volume. Therefore to stabilize one cubic meter of soil, a minimum of ¼ of the volume will be cement or lime for the mixture and this is seven bags for cement and 24 bags for lime.

2.6. Objectives of the study

The general objective of the study is to study stabilization of expansive clayey soils with PET plastic bottle strip wastes. The specific objectives of the study are:

1) To compare the maximum dry density and optimum moisture content values of the unreinforced soil with the values gained after reinforcement with PET plastic strips.

2) To investigate the effect of including PET plastic strips on the strength and compressibility of the soil based on values of compaction, liquid limit, plastic limit, and plasticity index.

CHAPTER 3
METHODOLOGY

3.1 Materials and Methods

3.1.1 Materials

1) There were two materials used for this study: a representative clay type soil. rectangular PET bottle strips.
2)The strips were prepared from waste plastic bottles that were collected from the nearby surroundings.
3)The bottles were cleaned properly after collection and cut into three different sized strips, manually using scissors (Figure 1).

Table 3.1 Different Sizes of Strips

STRIPS	WIDTH(MM)	LENGTH(MM)
1	4	7
2	8	14
3	12	18.5

Figure 3.1 Image of Different Shapes of PET

3.2. METHODS

3.2.1. Material Characterization

The characterization of the soil sample taken for this study included particle size distribution, Atterberg limit and specific gravity of soil tests. The sample soil taken was sieved in order to take out any other impurities and unnecessary particles.

It was then prepared for testing accordingly. Once sample preparation was done, sieve analysis and hydrometer analysis were conducted to study the particle size distribution of the soil. Plastic limit, liquid limit and plasticity index of the soil were determined by performing the Atterberg limit test.

The test was carried out using Casagrande's apparatus. Specific gravity of the soil on the other hand was determined from the specific gravity test in the geotechnical laboratory. A specific gravity beaker and vacuum pump were used to carry out the test as per . The specific gravity was taken as the ratio of the density of soil to the density of water at the same temperature.

The PET fibers on the other hand were characterized as per size (length, width and thickness), surface texture, shape and color.

3.2.2. Material Mixing Method and Proportions

The plastic strips, which are expected to act as soil reinforcements, were added to the soil in three different percentages (0.5%, 1% and 2%) by mass of the soil. Percentage by mass represents the ratio of mass of plastic to mass of soil sample taken as a percentage.

3.2.3. Methods of Testing Soil Properties

Once the characterization of both materials was complete, the plastic bottle strips were added to the soil sample in the treatment levels described above. Free swell test, standard proctor compaction test, direct shear test, Unconfined Compressive Strength (UCS) test and California Bearing Ratio (CBR) test were carried out in order to study the effect of the addition of the plastic strips on clay soil.

Figure 3.2 Method of Testing of Soil properties

3.3 Soil properties

3.3.1.Atterberg Limits

1) Shrinkage Limit: This limit is achieved when further loss of water from the soil does not reduce the volume of the soil. It can be more accurately defined as the lowest water content at which the soil can still be completely saturated. It is denoted by wS.

2) Plastic Limit: This limit lies between the plastic and semi-solid state of the soil. It is determined by rolling out a thread of the soil on a flat surface which is non-porous.

3)It is the minimum water content at which the soil just begins to crumble while rolling into a thread of approximately 3mm diameter. Plastic limit is denoted by wP.

3) Liquid Limit: It is the water content of the soil between the liquid state and plastic state of the soil. It can be defined as the minimum water content at which the soil, though in liquid state, shows small shearing strength against flowing.

4)It is measured by the Casagrande's apparatus and is denoted by wL.

Table 3.2 Plastic Limit Determination Record

Determination Number	1	2	3
Container Number	I	II	III
Weight of Container	26.10	21.86	25.91
Weight of Container + Wet Soil	32.29	34.74	30.15
Weight of Container + Oven - Dry Soil	31.29	32.51	29.06
Weight of Water	1.09	2.23	1.09
Weight of Oven + Dry Soil	5.10	10.65	5.15
Water Content	21.37	20.84	21.17
Plastic Limit = 21.16%			

Table 3.3 Specific Gravity By Density Bottle

OBSERVATIONS	I	II	III
Weight of Density Bottle	16.94	16.94	16.94
Weight of Density Bottle + Dry Soil	31.60	40.26	39.12
Weight of Density +Soil + Water	84.67	89.90	89.62
Weight of Density + Water	75.62	78.62	75.62

Specific Gravity = 2.78

Figure 3.3 Plastic Limit

3.3.2.Particle Size Distribution

Soil at any place is composed of particles of a variety of sizes and shapes, sizes ranging from a few micrometers to a few centimeters are present sometimes in the same soil sample. The distribution of particles of different sizes determines many physical properties of the soil such as its strength, permeability, density etc.

Particle size distribution is found out by two methods, first is sieve analysis which is done for coarse grained soils only and the other method is sedimentation analysis used for fine grained soil samples. Both are followed by plotting the results on a semi-log graph.

The percentage finer N as the ordinate and the particle diameter i.e. sieve size as the abscissa on a logarithmic scale. The curve generated from the result gives us an idea of the type and gradation of the soil. If the curve is higher up or is more towards the left, it means that the soil has more representation from the finer particles; if it is towards the right, we can deduce that the soil has more of the coarse grained particles.

The soil may be of two types- well graded or poorly graded (uniformly graded). Well graded soils have particles from all the size ranges in a good amount. On the other hand, it is said to be poorly or uniformly graded if it has particles of some sizes in excess and deficiency of particles of other sizes. Sometimes the curve has a flat portion also which means there is an absence of particles of intermediate size, these soils are also known as gap graded or skip graded. For analysis of the particle distribution, we sometimes use D10, D30, and D60 etc. terms which represent a size in mm such that 10%, 30% and 60% of particles respectively are finer than that size. The size of D10 also called the effective size or diameter is a very useful data.

There is a term called uniformity coefficient Cu which comes from the ratio of D60 and D10, it gives a measure of the range of the particle size of the soil sample.

3.3.3 Specific gravity

Specific gravity of a substance denotes the number of times that substance is heavier than water. In simpler words we can define it as the ratio between the mass of any substance of a definite volume divided by mass of equal volume of water. In case of soils, specific gravity is the number of times the soil solids are heavier than equal volume of water.

Figure 3.4 Soil Sample For Testing

Figure 3.5 Casagrande's aperture

3.4 Shear strength:-

Shearing stresses are induced in a loaded soil and when these stresses reach their limiting value, deformation starts in the soil which leads to failure of the soil mass. The shear strength of a soil is its resistance to the deformation caused by the shear stresses acting on the loaded soil. The shear strength of a soil is one of the most important characteristics. There are several experiments which are used to determine shear strength such as DST or UCS etc.

The shear resistance offered is made up of three parts:

i) The structural resistance to the soil displacement caused due to the soil particles getting interlocked,

ii) The frictional resistance at the contact point of various particles, and

iii) Cohesion or adhesion between the surface of the particles. In case of cohesionless soils, the shear strength is entirely dependent upon the frictional resistance, while in others it comes from the internal friction as well as the cohesion.

3.4.1 Methods for measuring shear strength:

a) Direct Shear Test (DST) This is the most common test used to determine the shear strength of the soil. In this experiment the soil is put inside a shear box closed from all sides and force is applied from one side until the soil fails. The shear stress is calculated by dividing this force with the area of the soil mass. This test can be performed in three conditions- undrained, drained and consolidated undrained depending upon the setup of the experiment.The angle of internal fric- tion and cohesion intercept of the unreinforced soil was found to be 5.710 and 49.83 kPa respectively. The small value of friction angle is attributed to the cohe- siveness of the soil. The largest values of C and φ for the reinforced soil was ob- tained as 8.980 and 62.67 Kpa which was a 57% and 26% improvement respectively.

b) Unconfined Compression Test (UCS test) This test is a specific case of triaxial test where the horizontal forces acting are zero. There is no confining pressure in this test and the soil sample tested is subjected to vertical loading only. The specimen used is cylindrical and is loaded till it fails due to shear.The UCS of unreinforced soil was found to be 151.8 kPa. The largest improvement in the UCS is 316.4 kPa that is a net increase of 108% which is a tremendous growth.

3.5 Test methods:-

Test Performed Standard Used :-

1)Free swell test

2)Standard proctor compaction test

3) Direct shear test

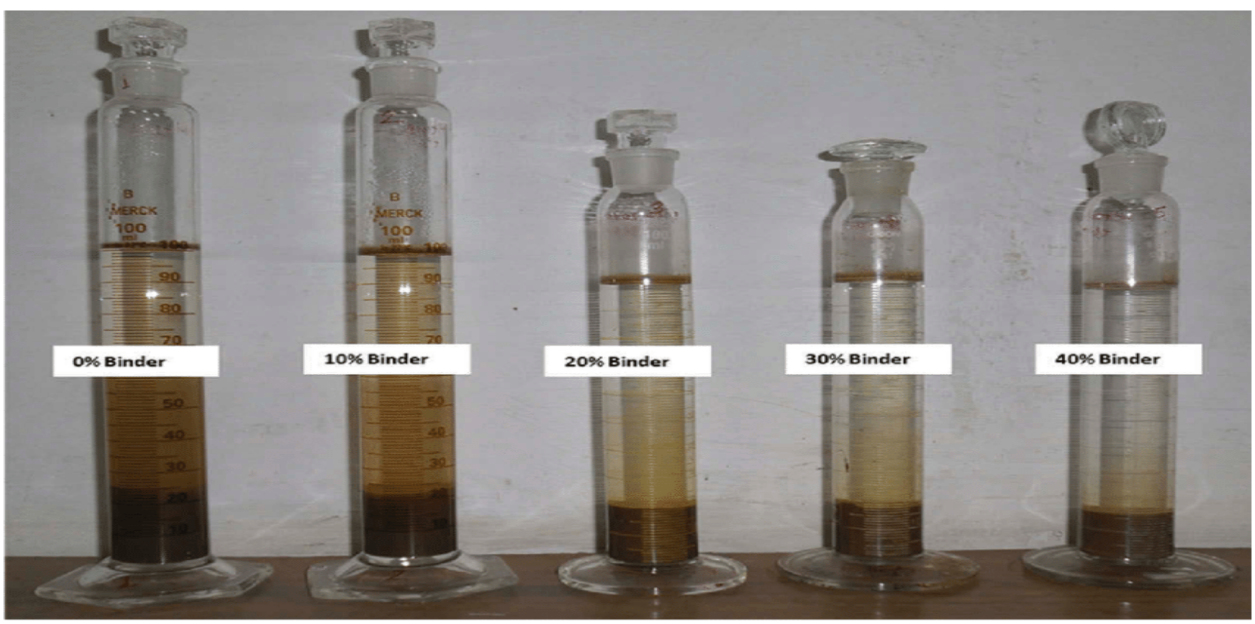
4)Unconfined Compressive Strength (UCS) test

5) California Bearing Ratio (CBR) test

3.5.1. Free swell test

The swelling of the soil sample was studied by conducting the free swell test. In this test, a 10 g of oven-dried soil sample passing through a number 40 sieve (425 μm) was put into a graduated free-swell jar with capacity of 100 ml, and filled with water. The sample was left until it reached its maximum swelling level. Then the recorded value was computed with respect to the original 10 ml volume and expressed in percentage. free swell jars set for settling.

The maximum dry density and optimum moisture content were determined by conducting standard proctor compaction tests. In this test, the soil was compacted using a test mold and a rammer at different water contents until the wet density started decreasing . Moisture content of the soil at different water additions was obtained, and the dry density for each compaction level was graphed with its respective water content. The peak of the curve provides the maximum dry density that the soil can be compacted to, with the optimum moisture content that can yield the maximum compaction.The response of a consolidated and drained soil sample for direct shear, and results in the shear strength of the soil were determined by conducting a direct shear test. The test was performed by deforming a specimen at a controlled strain rate on a single shear plane, which is determined by the configuration of the apparatus.Generally, three specimens were tested, each under a different normal load, to demonstrate the effect of surcharge and structural load upon shear resistance and displacement. The shear results at the three normal loads are plotted on one graph and linearly fitted to result the average shear strength (C) of the soil, whereas the angle of internal friction (φ) is calculated from the slope of the line that is used to fit the shear strength values.illustrates the procedures of a direct shear test.



[Figure 3.6 Free swell test for expansive soil , Source:Google]

3.5.2. Standard proctor compaction test

Compaction is the process of densification of soil by reducing air voids. The degree of compaction of a given soil is measured in terms of its dry density. The dry density is maximum at the optimum water content. A curve is drawn between the water content and the dry density to obtain the maximum dry density and the optimum water content.

a) Equipments for Proctor's Test for Compaction of Soil

1) Compaction mold, capacity 1000ml.

2) Rammer, mass 2.6 kg

3) Detachable base plate

4)Collar, 60mm high

5)IS sieve, 4.75 mm

6)Oven

7)Desiccator

8)Weighing balance, accuracy 1g

9)Large mixing pan

10)Straight edge

11)Spatula

12)Graduated jar

13)Mixing tools, spoons, trowels, etc.

b) Proctor Soil Compaction Test Procedure

1) Take about 20kg of air-dried soil. Sieve it through 20mm and 4.7mm sieve.

2)Calculate the percentage retained on 20mm sieve and 4.75mm sieve, and the percentage passing 4.75mm sieve.

3) If the percentage retained on 4.75mm sieve is greater than 20, use the large mold of 150mm diameter. If it is less than 20%, the standard mould of 100mm diameter can be used. The following procedure is for the standard mould.

4) Mix the soil retained on 4.75mm sieve and that passing 4.75mm sieve in proportions determined in step (2) to obtain about 16 to 18 kg of soil specimen.

5)Clean and dry the mould and the base plate. Grease them lightly.

6) Weigh the mould with the base plate to the nearest 1 gram.

7) Take about 16 – 18 kg of soil specimens. Add water to it to bring the water content to about 4% if the soil is sandy and to about 8% if the soil is clayey.

8) Keep the soil in an air-tight container for about 18 to 20 hours for maturing. Mix the soil thoroughly. Divide the processed soil into 6 to 8 parts.

9) Attach the collar to the mould. Place the mould on a solid base.

10) Take about 2.5kg of the processed soil, and hence place it in the mould in 3 equal layers. Take about one-third the quantity first, and compact it by giving 25 blows of the rammer. The blows should be uniformly distributed over the surface of each layer.

11) The top surface of the first layer is scratched with spatula before placing the second layer. The second layer should also be compacted by 25 blows of rammer. Likewise, place the third layer and compact it.

12) The amount of soil used should be just sufficient to fill the mould and leave about 5 mm above the top of the mould to be struck off when the collar is removed.

13) Remove the collar and trim off the excess soil projecting above the mould using a straight edge.

14) Clean the base plate and the mould from outside. Weigh it to the nearest gram.

15) Remove the soil from the mould. The soil may also be ejected out.

16) Take the soil samples for the water content determination from the top, middle and bottom portions. Determine the water content.

17) Add about 3% of the water to a fresh portion of the processed soil, and repeat the steps 10 to 14.

[Figure 3.7 Proctor Compaction Test Apparatus, Source:Google]

[Figure 3.8 Proctor Compaction Test, Source:Google]

3.5.3. Direct shear test

The purpose of a direct shear test is to determine the shear strength of a soil; this is done by forcing the soil to shear along an induced horizontal plane of weakness at a constant rate.Easy to prepare the sample. Convenient and simple test. The drainage is quick and the pore pressure dissipates very rapidly because the thickness of the sample is relatively small. Consolidated- undrained and drained tests take a small period of time

a)Apparatus

1. Direct shear box apparatus
2. Loading frame (motor attached).
3. Dial gauge.
4. Proving ring.
5. Tamper.

6. Straight edge.

7. Balance to weigh upto 200 mg.

8. Aluminum container.

9. Spatula

b) PROCEDURE

1. Check the inner dimension of the soil container.

2. Put the parts of the soil container together.

3. Calculate the volume of the container. Weigh the container.

4. Place the soil in smooth layers (approximately 10 mm thick). If a dense sample is desired tamp the soil.

5. Weigh the soil container, the difference between these two is the weight of the soil. Calculate the density of the soil.

6. Make the surface of the soil plane.

7. Put the upper grating on stone and the loading block on top of soil.

8. Measure the thickness of the soil specimen.

9. Apply the desired normal load.

10.Remove the shear pin.

11. Attach the dial gauge which measures the change of volume.

12. Record the initial reading of the dial gauge and calibration values.

13. Before proceeding to test check all adjustments to see that there is no connection between two parts except sand/soil.

14. Start the motor. Take the reading of the shear force and record the reading.

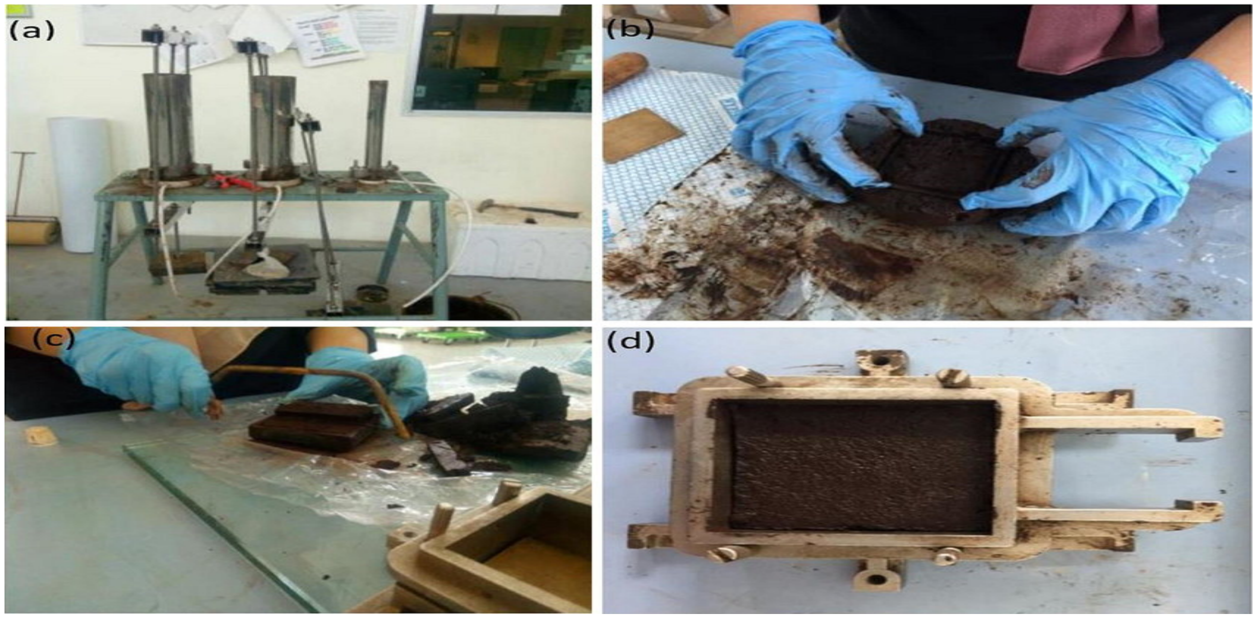
15.Take volume change readings till failure.

16. Add 5 kg normal stress 0.5 kg/cm^2 and continue the experiment till failure

17. Record carefully all the readings. Set the dial gauges zero, before starting the experiment

[Figure 3.9 Direct Shear test Apparatus, Source:Google]

The Direct Shear Test is an experimental procedure conducted in geotechnical engineering practice and research that aims to determine the shear strength of soil materials. Shear strength is defined as the maximum resistance that a material can withstand when subjected to shearing.Generally, the Direct Shear Test is considered one of the most common and simple tests to derive the strength of a soil and can be performed on undisturbed or remolded samples.



[Figure 3.10 Direct Shear Test, Source:Google]

c) Advantages of direct shear test

i) The test is relatively simple to carry out.

ii) The basic principle is easily understood.

iii) Preparation of recompacted test specimens is not difficult.

iv) Consolidation is relatively rapid due to the small thickness of the test specimen.

v) The principle can be extended to gravelly soils and other materials containing large particles, which would be more expensive to test by other means.

vi) Friction between rocks and the angle of friction between soils and many other engineering materials can be measured.

vii) In addition to the determination of the peak strength at failure, the apparatus can be used for the measurement of residual shear strength by the multi-reversal process.

d) Disadvantages of direct shear test

i) The specimen is constrained to fail along a predetermined plane of shear.

ii) The distribution of stresses on this surface is not uniform.

iii) The actual stress pattern is complex and the directions of the planes of principal stresses rotate as the shear strain is increased.

iv) No control can be exercised over drainage, except by varying the rate of shear displacement.

v) Pore-water pressures cannot be measured.

vi) The deformation which can be applied to the soil is limited by the maximum length of travel of the apparatus.

3.5.4.Unconfined Compressive Strength (UCS) test

The unconfined compressive strength (UCS) test was used to determine shear capacity of the sample soil under compression.The sample was extruded and cut into the standard cylindrical shape. The UCS machine was used to compress the sample and both the applied load and change in length of the sample were recorded.The values were tabulated and computed to get one representative value.

a) APPARATUS

1) Compression machine

2) Dial Gauge

3) Proving Ring

4) Split mold of internal diameter 30 mm and length 76 mm.

5) Sampling tube of internal diameter 30 mm and length 200 mm

6) Metal Plate

7) Moving Plate

8) Vernier calliper

9) Balance

10) Sampling extractor

b) PROCEDURE

Procurement of sampling tube with undisturbed sample from the site:-

1) Coat the inside of the split mould with a thin layer of grease or oil to prevent adhesion of the soil.

2)Extrude the specimen from the sampling tube to the split mould with the help of a sample extractor and knife.

3) Trim the two ends of the mould sample.

4) Remove the sample from mould by splitting it in two parts and weigh it. Also measure the length and diameter of the specimen.

5) Place the specimen on the bottom of the machine.

6) Raise the bottom plate of the machine to make contact with the specimen with the upper plate.

7)Adjust the strain dial gauge and the ring dial gauge to read zero.

8) Apply the compression load by raising the bottom of the machine to produce axial strain at a rate of 1.25 mm/min.

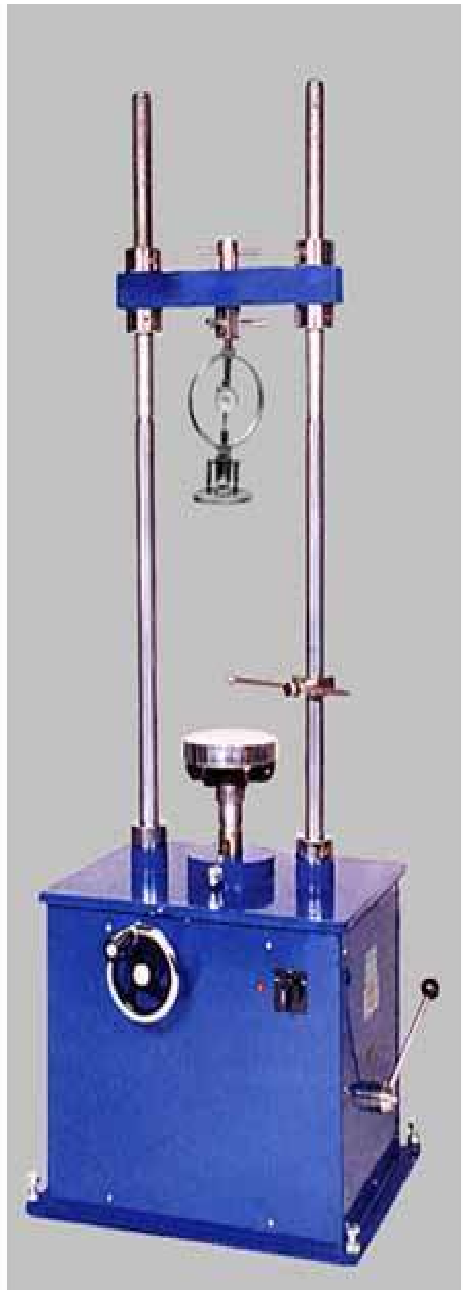
9)Record the strain and provide ring dial gauges reading every 30 sec.

10) Compress the specimen till it fails or 20% vertical deformation is reached whichever is earliest. Measure the failure angle from horizontal and note the load at failure.

11) Determine the water content of the specimen. The graph shows the sample deformation along the horizontal scale and the extension of the spring along the vertical scale.

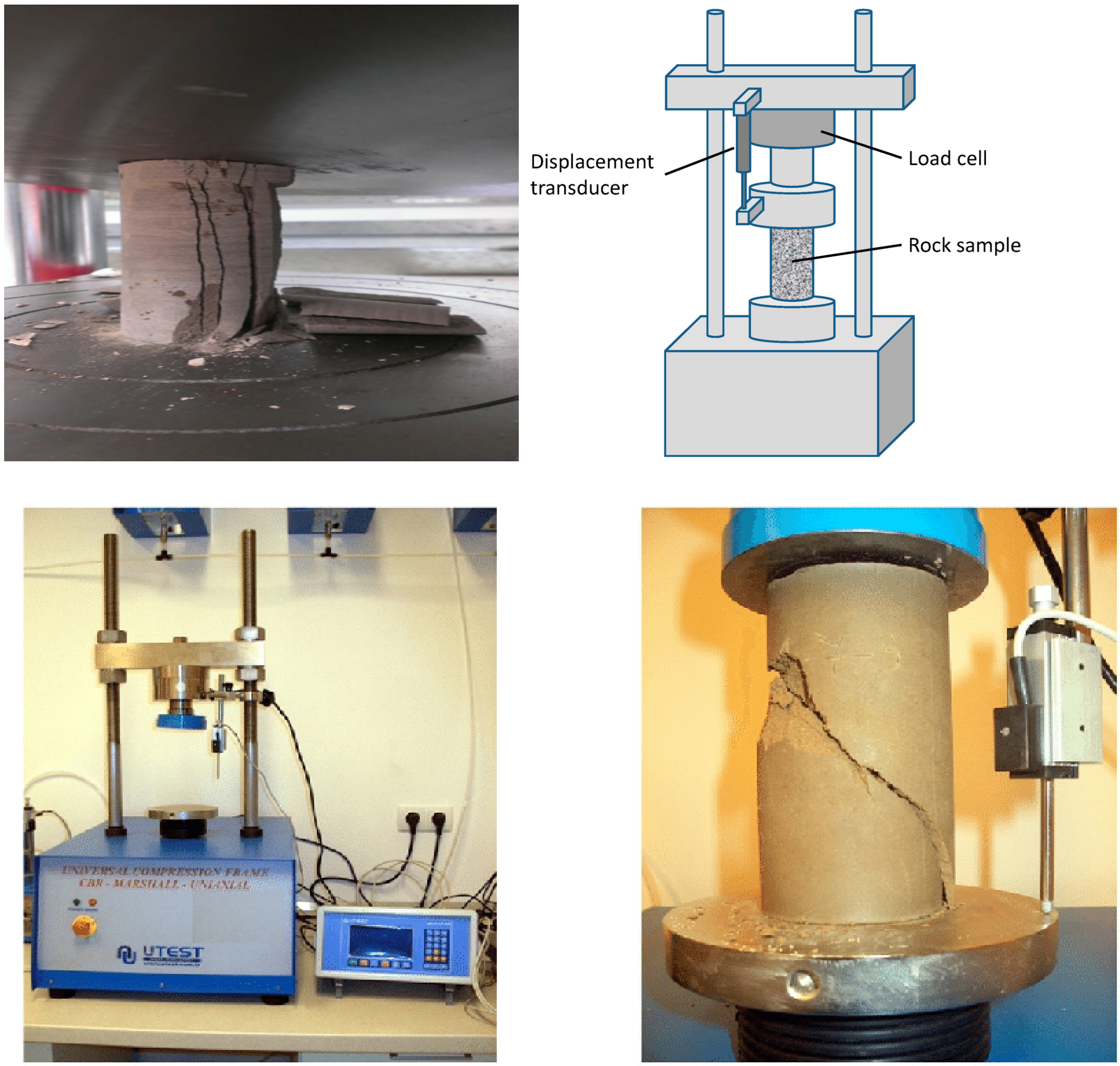
12) Two curves obtained shown in the next slide. The extension of the spring and corresponding deformation in the sample length (ΔL) can be read from the graph.

13) The stiffness of the spring multiplied by spring extension will give the total load Pf applied on the sample.



[Figure 3.11 unconfined compressive strength Apparatus, Source:Google]

It is not always possible to conduct the bearing capacity test in the field. Sometimes it is cheaper to take the undisturbed soil sample and test its strength in the laboratory. Also to choose the best material for the embankment, one has to conduct strength tests on the samples selected. Under these conditions it is easy to perform the unconfined compression test on undisturbed and remolded soil samples. Now we will investigate experimentally the strength of a given soil sample.



a. b.

[Figure 3.12 unconfined compressive strength test, Source:Google]

3.5.5. California Bearing Ratio (CBR) test

CBR test was conducted to measure the penetration strength of a compacted soil relative to crushed rock, which is considered to be an excellent base-course material. The results of a CBR

Tests help to understand the shear strength and bearing capacity of a soil sample. The test follows a compaction procedure combined with a penetration that is applied by a machine that applies a plunger load.

This test was used to simulate the effect of surcharge and excessive moisture on the compacted soil by putting a standard load that represents surcharge and soaking the mold for four days.

Table3.4 Required Equipments For Test

1. CBR Mould	Inside diameter 150 mm
2. Total height of mould	175 mm with detachable extension collar 50 mm high and detachable base plate 10 mm thick
3. Spacer Disc	148 mm diameter and 47.7 mm height
4. Rammers	For light compaction – 2.6 kg @ 310 mm drop and For heavy compaction – 4.89 kg @ 450 mm drop
5. Slotted Masses	Annular 2.5 kg each, 147 mm diameter with hole, 53 mm diameter in the center
6. Penetration Piston	50 mm dia and 100 mm long
7. Loading Device	Capacity 50 kN, movable head at a uniform rate 1.25 mm/min
8. Two Dial Gauge	Accuracy 0.01 mm
9. IS sieves	4.75 mm and 20 mm size
10. Expansion measuring Apparatus	Perforated plate of 148 mm diameter

a) CBR Test Procedure

1)Normally 3 specimens each of about 7 kg must be compacted so that their compacted densities range from 95% to 100% generally with 10, 30 and 65 blows.

2)Weight of empty mould.

3)Add water to the first specimen (compact it in five layers by giving 10 blows per layer).

4) After compaction, remove the collar and level the surface.

5) Take samples for determination of moisture content.

6) Weight of mould + compacted specimen.

7) Place the mold in the soaking tank for four days (ignore this step in case of unsoaked CBR.

8) Take other samples and apply different blows and repeat the whole process.

9) After four days, measure the swell reading and find %age swell.

10)Remove the mould from the tank and allow water to drain.

11) Then place the specimen under the penetration piston and place a surcharge load of 10lb.

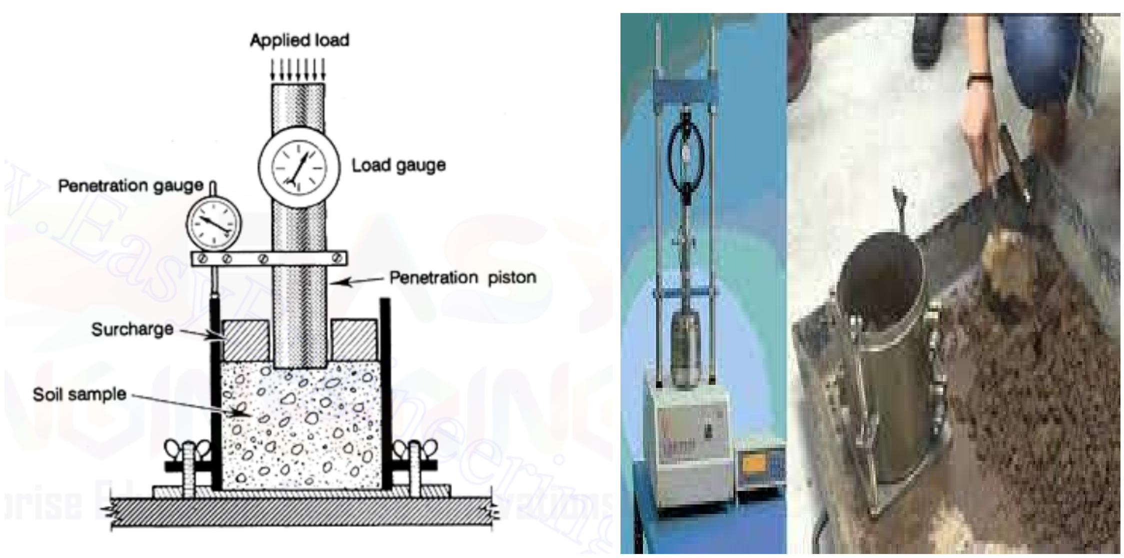
12) Apply the load and note the penetration load values.

13) Draw the graphs between the penetration (in) and penetration load (in) and find the value of CBR.

14) Draw the graph between the %age CBR and Dry Density, and find CBR at required degree of compaction.

[Figure 3.12 California Bearing Ratio CBR Apparatus, Source:Google]

The harder the material, the higher the CBR value. A CBR value of 2% is usually found for clay, high-quality sub-base will have CBR values between 80% and 100%, and some sands may have values around 10%.The CBR testing can be applied to soils with a maximum particle size of 20 mm. For soils with bigger particles, other types of bearing capacity can be used like the Plate Bearing Test.Since the coarse-grained soils and fine-grained soils have particles with size smaller than 20 mm, they can be evaluated by the CBR testing.



[Figure 3.13 California Bearing Ratio CBR Test, Source:Google]

CHAPTER 4

RESULT AND DISCUSSION

4.1. Characterization of Soil

The characterization of the soil sample was done according to particle size distribution, Atterberg limit tests and specific gravity of soil test.

The results showed that the soil was a fine-grained clay soil with a specific gravity of 2.78 as well as a liquid limit of 94.2%, a plastic limit of 28.3% and a plasticity index, which is the difference between the liquid and plastic limit of 65.9%.

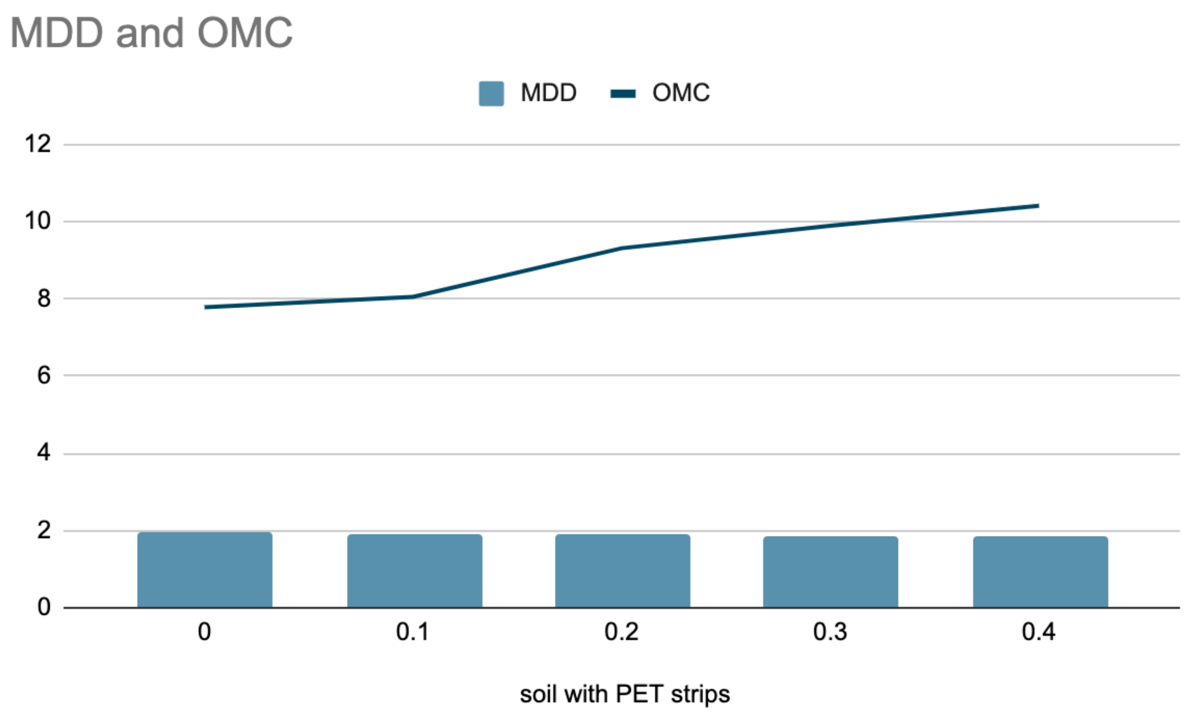
4.2. Testing Reinforced Soil Properties

4.2.1. Standard Proctor Compaction Test

Results One of the ways the effect of adding plastic into the soil was checked was in terms of the soil's improvement during compaction. This improvement was expressed in the change in the maximum dry density (MDD) and optimum moisture content (OMC). The summary of the test results is All strip sizes showed reduction in optimum moisture content as the percentage of plastic increased.

Table 4.1 RESULT OF MDD AND OMC

Sample Description	MDD(g/cc)	OMC(%)
Soil with no PET strips	1.946	7.78
Soil with 0.1% PET strips	1.911	8.05
Soil with 0.2% PET strips	1.896	9.31
Soil with 0.3% PET strips	1.843	9.89
Soil with 0.4% PET strips	1.837	10.41



[figure 4.1MDD & OMC varies with different percentages of clay soil]

A largest reduction is obtained at a strip size of 4 × 7 (mm) at a 2% addition which yielded a 31% decrease in the moisture content. The reason for the decrement of the OMC might be because of zero absorption.capacity of the plastic strips for water. Therefore, soil can be compacted to its maximum dry density at lower addition of water, which is a very good improvement. the comparisons between OMC of the soil at the different sizes and percentages of plastic addition.

A decrease in maximum dry density of the soil is also noted but it is marginal. The largest reduction occurred at a strip size of 8 mm × 14 mm at 2% content which is 7% only. Only the 2% content of the 4 × 7 (mm) strip maintained the maximum dry density of the original soil, which is 12.8 kN/m3 . The addition of less dense material, which is the plastic, in the soil might have decreased the density of the soil. However, the reduction in maximum dry density is counterbalanced by the decrease in optimum moisture content. The decreased density of soil has an engineering application in lightweight embankment construction. shows the comparisons between MDD of the soil at the different sizes and percentages of plastic addition.

4.2.2. Free Swell Test

Results The main problem of expansive soil is its volume change in different moisture conditions. When the moisture content increases, the soil swells and its volume increases in a wide range from the original. This property happens at a particle level, when water particles break the bonds that connect the sandwich-like chemical structure and penetrate between layers. This problem is particularly solved by altering the chemical characteristics of the soil using the application of different chemicals. As for this project, the plastic strip was proposed to act as a physical agent and was expected to decrease the swelling potential of the soil. From visual inspection during experiments and the results from free-swell tests for the soil containing different percentages of plastic strips, there is no chemical bonding between the soil and the strip. Therefore, the reduction in swelling is a sole effect of the physical interaction between the soil and the strip.

The free swell of unreinforced soil is observed to be 160% which according to ASTM is classified as very highly expansive soils. A substantial reduction in the free swell of the soil is observed due to the addition of plastic strips. A 30% reduction in swell occurs at strip size of 5 ×
7.5 (mm) and strip content of 2%. Table 5 gives a summarized version of the swelling test results for each plastic strip size and treatment level (percentage).

The free-swell test uses 10 g of sample in a standard graduated free-swell jar. On the addition of the plastic in the soil, the mass of the soil has to decrease so that the total mass of the plastic and the soil will become 10 g.

The reason for the decrease in the swelling potential was not because of chemical interaction. But it was due to the amount of soil mass decreased, which is equal to the mass of the plastic added. Since decreased mass of the soil was replaced by non-swelling material, the swelling showed some improvement. The soil-plastic interaction might also have an effect in reducing the free swell.

4.2.3. Direct Shear Test Results

It was possible to conclude from the test results that the arrangement of the plastic strips in the soil affects the shear capacity of the reinforced soil. If the surface of the strip is parallel to the shear plane, the shearing will be enhanced and the capacity will fail. But any other arrangement will improve the shear capacity of the soil. On the other hand, it was difficult to arrange the larger sizes of strips in on the direct shear machine, as their surface area was close to that of the shear box.

The shear capacity from the tests is presented in terms of the shear strength parameters, cohesion (C) and angle of internal friction (φ). Both improvement and drop of shear capacity were recorded for C and φ. The angle of internal friction and cohesion intercept of the unreinforced soil was found to be 5.710 and 49.83 kPa respectively. The small value of friction angle is attributed to the cohesiveness of the soil. The largest values of C and φ for the reinforced soil was obtained as 8.980 and 62.67 Kpa which was a 57% and 26% improvement respectively. These results were obtained for the 12 * 18.5 strip size at 0.5%. the C and φ results obtained for each treatment level and strip sizes. Increasing the plastic content for the same plastic strip size has increased both the friction angle and cohesion for 4 × 7 (mm) and 8 × 14 (mm) strips but decreased for 15 × 20 (mm). However, increasing the plastic size for the same content increases the friction angle and cohesion. Unconfined Compressive Strength (UCS) Test Results The results found from the unconfined compressive strength (UCS) test, were different from the direct shear results. The UCS of unreinforced soil was found to be 151.8 kPa. The largest improvement in the UCS is 316.4 kPa that is a net increase of 108% which is a tremendous growth. The rise in UCS is obtained at small strip contents and sizes. Increase in size generally reduces the UCS value. When the applied compressive stress forced the soil mass to slide over the surface of plastic strips and the lack of confinement might have contributed for the reduction of the UCS value. The UCS mold is also small and it might have caused large un-compacted shear planes.

4.3 Cracking and Shrinking

The decrease in moisture content of expansive soil results in wide and deep cracking. This phenomenon results in a decrease in volume, and consequently the soil is excessively compressed. Many structures lost their stability and failed due to less awareness and treatment of this character of expansive soil. The addition of plastic strips can help reduce the cracking and shrinking characters of the soil by bridging between the cracks. This was witnessed when the compacted soil was extruded from the mold and left to air dry until it fully cracked. The cracks outlined on the surface of the molded soil and its ability to maintain its original spherical shape were compared by visual inspection. The strip size of 4 × 7 (mm) resulted in a very considerable reduction of cracking, while larger sizes especially at higher percentages decreased the ability of the soil to maintain its spherical shape of mold. It was obvious that the larger surface area of the plastic, the easier for the soil to crack. It can clearly be seen from the figure that the sample containing 12x18.5 plastic strip sizes showed excessive cracking.

4.4 California Bearing Ratio (CBR)

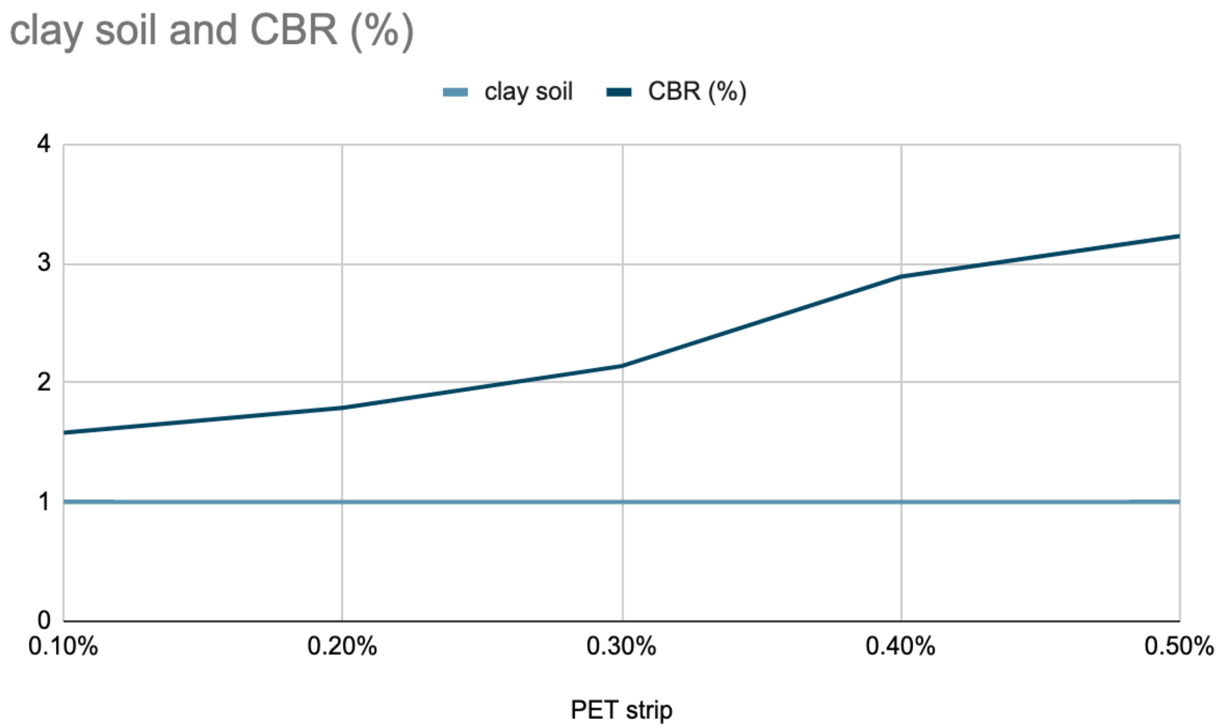
Test Results the bearing capacity of the soil was measured indirectly by conducting the CBR test. The Soaked CBR is only tested in this study because it is the only test that simulates actual site conditions. Also, the study was focused on investigating the effect of water on expansive soils CBR value. The load penetration curve has shown that there is an improvement in the CBR value. The soaked CBR of unreinforced soil was found to be 1.58 which is small. The principal enhancement is attained at a strip size and content of 12 × 18.5 (mm) and 1% respectively and is of value 3.23. This is a total of 104% increment.

Increase in plastic size for the same percentage has resulted in an increase in soaked CBR value but increase in plastic content for the same plastic size increases the soaked CBR then decreases. The improvement in CBR can be attributed to the ability of the strips in resisting swelling prior to penetration and load exerted by the plunger during penetration.

4.4.1 CBR of Clay : PET Strips :

Table 4.2 CBR value of Clay soil : PET Strip

S.No.	Clay soil : PET strips	CBR(%)
1.	100%: 0.1%	1.58
2.	100%: 0.2%	1.79
3.	100% : 0.3%	2.14
4.	100% : 0.4%	2.89
5.	100% :0.5%	3.23



[Figure 4.2 CBR value of Clay soil : PET Strip]

CHAPTER 5
CONCLUSIONS

5.1 CONCLUSION

This paper assessed the method of stabilizing clay soils using plastic bottle strips. The following conclusions are drawn based on the analysis and interpretation of the results obtained.

1) A significant and marginal reduction was recorded in the optimum moisture content and in the maximum dry density results respectively.

2) The angle of internal friction and the cohesion intercept increased significantly as the reinforcement percentages and sizes increased. A huge improvement in UCS has been noted for smaller strip size and content.

3) Any further increase in size and content has brought reduction in UCS because increase in size causes un-compacted weak shear planes.

4) The swelling of the soil was reduced significantly at high percentages of strip content because of replacement in an equal mass of expansive soil by non-expansive plastic. Physical anchorage has also some effect in reducing the free swell.

5) The swelling reduction is in some way similar for different sizes at the same percentage which shows that the dominant factor that contributes to reduction in swelling is percent by weight of plastic content.

6) Increase in plastic size for the same percentage has resulted in an increase in soaked CBR value but increase in plastic content for the same plastic size increases the soaked CBR then decreases.

7) The optimum plastic size and plastic content that results in optimum result can be selected based on the importance of the selection parameter for a specified engineering work. In nutshell, stabilizing expansive clay soil with waste plastic bottle strips is a reliable alternative as it improves the volume fluctuation problems of the soil.

8) The strips were acting as reinforcements playing a role of arresting volume changes with change in water content. Incorporating waste plastic bottles in the construction industry also is a crucial way to solve the issue of insufficient plastic waste disposal.

9) The laboratory results presented in the study favorably suggest the possibility of utilizing plastic material as tensile inclusions in expansive soil to increase the resistance to shear, CBR value and reduction in swelling.

10) However, a better understanding of the interaction mechanism in soils reinforced with the plastic material would be essential to properly document the engineering behavior of the soil-plastic composite.

FUTURE SCOPE

In future a number of variations can be done and iterated to find the different set of results-

1) The same tests can be carried out with varying proportions and varying sizes.

2) The orientation of the strips provided can also be plastics may also be used in combination with other geotextiles or sand or with different types of cement and other soil stabilizing agents like fly ash and rice husk.

3) The test may also be iterated with waste or crushed plastic bottles filled with sand as a replacement of stone columns for stabilization.

4) Here we have conducted only a lab test but later on we can also create a model of an embankment and check for its altered properties using the Universal Testing Machine (UTM). 5) This technique can be effectively applied in construction of embankments proving it to be multipurpose because it not only strengthens but also preserves the environment.

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