ACBA 5009 WORK BASED PROJECT

THE EFFECTS OF WASTE PLASTIC MATERIALS ON THE STABILISATION OF CLAYEY SOIL

ACBA 5009 - Research Project

Mariah Edwards
2114464

Contents

Introduction 2
Literature Review 4
Methodology 6
Reference 11

Introduction

Topic: The effects of waste plastic materials on the stabilisation of clayey soil.

The process of soil stabilisation refers to the techniques used to alter the geotechnical properties of the soil to make it more suitable for specific project requirements. Various methods involve blending with other soils, incorporating a geo-material, or using chemical additives or stabilising agents such as lime, cement, fly ash, etc. (Patel, 19, 2019)

Geotechnical engineers often encounter soils in construction and infrastructure developments that are too weak or unstable, soil stabilisation is needed in these cases as it enhances the bearing capacity, shear strength and compressibility of problematic soils such as clays. Instead of excavating and replacing the unsuitable soils or even relocating the project which can all be costly and time consuming they apply ground improving techniques such as soil stabilisation. (Patel, 19, 2019)

The kind of clay soil, water content, and clay's tendency to change volume can all influence the hardening and softening in soils, this is referred to as 'shrink-swell' behaviour. This type of behaviour is common in fine-grained, clay-rich soils as they absorb a great amount of water after rain, becoming sticky and heavy and when dry, and they can also become incredibly hard, causing the earth to shrink and split.

Homes in various regions of the United Kingdom are affected by this shrink-swell behaviour. Subsidence can occur due to ground movement induced by changing meteorological conditions, such as dry summers or rainy winters. (BGS)

The bearing capacity, compressibility, drainage, swelling potential, and plasticity of clay soils are important properties for engineers. Clay soils often have a limited bearing capacity. This means that they are unlikely to sustain huge weights or buildings, posing a risk to the project's safety and stability. They are very compressible and can settle significantly when loaded. This can cause structural damage to buildings or other infrastructure built on clay soils. They also have limited permeability and are slow to drain, which can lead to water retention, producing soil instability and erosion. Clay soils are prone to swelling and shrinking when their moisture content varies. This can harm foundations and other buildings erected on top of the soil. Excavation is usually problematic for geotechnical engineers due to

the high plasticity in clay soils and the tendency to attach to excavation equipment. To address these obstacles, engineers employ specific procedures to stabilise clay soils, such as adding reinforcing materials, building drainage systems, or applying ground improvement techniques such as preloading or vibro-compaction and soil stabilisation. (Whitlow, 2001, pp. 11-12)

Understanding the specific features and problems of clay soils is critical for the successful completion of geotechnical engineering projects. These features influence the technique of stabilisation, which might be chemical or mechanical. Applying these strategies is dependent not only on the soil characteristics, but also on the project site and the requirements of the structure to be erected. (Patel,19, 2019)

Mechanical stabilisation is accomplished by combining and compacting two or more soils and/or aggregates into a dense, well-graded mixture. (Patel, 19,2019)

Chemical stabilisation is the modifying of soil characteristics by the use of various additives such as lime, cement, fly ash, etc., or through the addition of chemicals, resins, and enzymes. (Patel, 21, 2019)

With a greater emphasis on environmental preservation, several nations building sectors are now compelled to utilise waste materials for various uses. With this in mind, there is plenty of room for new requirements and guidelines, as well as enhanced technology and ways for effectively utilising waste materials for soil stabilisation. Furthermore, with rapidly changing climatic circumstances, global warming, and the necessity to apply the soil-stabilization process in new, untested, or severe environmental settings, it is critical to create new chemicals and other additives, as well as novel field-implementation approaches. Extensive study is necessary to lower the costs of the various stabilising procedures as well as the time required to attain the desired soil characteristics. (Patel, 27, 2019)

According to a recent OECD estimate, the world is generating twice as much plastic waste as it did two decades ago, with just 9% properly recycled.

Plastic usage has doubled over the previous 30 years, raising concerns about the accumulation and plastic contamination. This highlights the significance of better waste management and increased recycling.

The OECD emphasises the need for plastic waste solutions, since global plastic waste is expected to almost treble by 2060. (OECD, 2022)

The construction industry is primarily to blame for the plastic waste problem. It accounts for around 10 million tonnes of plastic demand in Europe, according to figures from the trade association plastics Europe, making it the second largest sector after packaging. A percentage of the packaging is also utilised in construction sector, which further increases the sector's effect.

90% of all plastic garbage is composed of six different types, with PVC being the most common and accounting for about half of all plastics waste, followed by polypropylene and polyethylene.

Nevertheless, a growing industrial emphasis on material reuse and recycling, embodied carbon, and the circular economy has shifted the discussion and accelerated efforts to decrease plastic waste. (RICS, 2022)

Plastics are a type of material that may be moulded when soft and then solidified to keep its shape. These materials can be both synthetic and natural. Plastics are made up of polymers, which are materials made up of many repeating units. Polymers are often classified as thermosetting, thermoplastic, or elastomeric depending on their physical qualities. (Lyons, 2019)

Polyethylene Terephthalate (PET), a kind of polyethylene, belongs to the polyester family. It is constructed of one of the most affordable polymers. The majority of it comes from water bottles. It is more resistant to chemicals and absorbs less water. In its present state, it is highly flexible, rigid, and ductile. (Lyons, 2019)

Geotechnical engineers assess the effectiveness of soil stabilisation using a variety of tests and analyses. These include tests that evaluate the shear strength, compressibility, and bearing capacity of the soil, as well as tests to measure its permeability, porosity, and other physical parameters. (Lutenegger, 2019,333- 334)

Literature Review

There are a number of experimental papers available on the use of plastics to improve geotechnical parameters of various soil types. A few of these are noted below.

Stabilisation of soil with waste plastic bottles (2021) by Gangwar, Preeti and Tiwari,Sachin

This research paper investigates the use of plastic as a stabilizing agent for soil. Different percentages of plastic waste were added to soil samples and various laboratory tests were conducted, including Unconfined Compressive Strength, California Bearing Ratio, and Proctor Test. Results showed that adding 0.5% of plastic waste as a replacement for dry soil weight improved the moisture-density relationship of the soil. However, increasing the percentage of plastic waste led to a decrease in dry density and an increase in optimum moisture content. The CBR value was increased with the addition of 1% waste plastic but reduced as the percentage of waste plastic increased. The unconfined compressive strength and shear strength of the soil increased slightly with the addition of 0.5% plastic but decreased with further additions of plastic waste. (Preeti et al,2021,3802-3806)

Experimental Study on Effect of Waste Plastic Bottle Strips in Soil Improvement PEDDAIAH, S., BURMAN, A. and SREEDEEP, S., (2018)

PET waste, water bottles were cut into strips with width and length of (15 mm 9 15 mm), (15 mm 9 25 mm), and (15 mm 9 35 mm). The standard Proctor Test, Direct Shear Test, and California bearing ratio (CBR) tests were done without plastic strips, whereas the identical series of tests is performed with plastic strips at varied percentages of 0.2, 0.4, 0.6, and 0.8%. This study investigates the influence of plastic bottle strips on silty sand using a series of compaction, direct shear, and California bearing ratio (CBR) experiments with variable percentages of plastic strips and aspect ratios in terms of size. The results show that plastic reinforcing in soil increases maximum dry unit weight, shear strength parameters, and CBR value significantly.

Experimental investigation on using plastic wastes to enhance several engineering properties of soil through stabilisation Irfan Ahmad Wani [a], Irfan Majeed Sheikh [b], Tahir Maqbool [a], Virender Kumar [a] (2021)

A variety of experiments on the soil sample were performed to assess the improvement in engineering qualities, including the standard proctor test, unconfined compression test, and California bearing ratio test. Many studies were conducted on the sample when it was mixed with plastic fibres.

An unconfined compression strength test revealed that at 0.5% plastic waste addition to soil sample, the maximum compressive strength of 0.04 N/mm2 occurs, which is much less than the 0.022 N/mm2 of normal soil.

According to the California bearing ratio test, the highest CBR value of 2.45 occurs at 1.0% plastic waste addition to soil sample, which is less than 1.85 for normal soil.

A study on the effect of waste plastic strips in the stabilisation of clay soil- Saravanan, R; Murthi, P; Poongodi, K; Raju, Adigoppula. (2020)

The synthetic pieces were incorporated at three different blending proportions (0.5%, 1%, and 1.5%) by mass of soil with different aspect ratios (8*8mm, 8*16mm, and 8*24mm).

The Proctor compaction test, free swell test, shear test, Unconfined Compressive strength test (UCS), and California Bearing Ratio (CBR) tests were used to investigate the effects of incorporating these plastic strip pieces into clay soil.

The swell potential index decreased dramatically as the strip content increased. When plastic strips are applied to clay, the friction between the clay soil and the strips increases, improving the bonding force between soil particles. The insertion of plastic strip enhances compressive strength. When the CBR value rises, the thickness of flexible pavement falls.

Methodology

The aim of this lab experiment is to investigate the effect of waste plastic materials on clayey soils. This will be accomplished by a series of experiments, which will include a sieve analysis, the Atterberg limit test, and the direct shear test. The tests will be carried out in accordance with BS EN ISO 17892-4:2016, BS EN ISO 17892-12:2018+A1:2021, and BS EN ISO 17892-10:2018.

In this experiment, waste PET plastic bottles would be collected and shredded. To analyse and categorise the soil's characteristics, a dry sieve test and analysis would be performed in conjunction with an Atterberg limit test. The soil sample would then be subjected to a direct shear test without the addition of any waste plastic materials, this would then be the control sample. The direct shear test would then be performed three times with the PET waste plastic material added in percentages of 2, 5, and 9% each time. The results would then be compared to the control sample that had

no waste plastic added to determine the impact of the waste plastic components on the soil sample.

The sieve analysis is performed to determine the particle size distribution. It is one of the most significant physical properties of soil. The particle size distribution of soil influences several geotechnical parameters. Sieves, a mechanical sieve shaker, a balance, and an oven are required for this test. The soil sample will be placed on top of the sieves and shaken for a predetermined period of time. After shaking, the weight of each sieve and its retained particles will be determined. This test will be carried out in accordance with British Standard BS EN ISO 17892-4.

Apparatus:

- Set of test Sieves with the following aperture size: 2 mm, 1.6 mm, 1mm, 500um, 250 um, 125 um, 80 um and 63 um.
- Mechanical sieve shaker
- Drying oven
- Test specimen containers
- Scale
- Scale pan

Ancillary Apparatus

- A scoop
- Sieve brushes

Sieve Analysis Test:

1. Select the soil sample by quartering and riffling.
2. Weigh approximately 1000 g of the air-dried clay soil sample using a weighing balance.
3. Place the soil sample in an oven at 110°C for 24 hours to remove any moisture content.

4. Take out the soil sample from the oven and leave it to cool to room temperature.
5. Weigh the scale pan and zero it on the scale.
6. Weigh the dried soil sample and record the weight.
7. Set up and secure the sieve shaker with the set of sieves in decreasing order of size.
8. Pour the soil sample into the top sieve (20 mm) and place the sieve shaker in motion for 10 minutes.
9. Weigh the residue left on each sieve and record the weight.
10. Calculate the percentage of soil retained on each sieve and plot the results on a graph.
11. Plot percentages on the triangular graph of soil texture.

(British Standards Institution, 2016)

The Atterberg Limits test will be used to establish the moisture content at which the soil changes from a plastic condition to a liquid state and back again. The test would be carried out in accordance with British Standard BS EN ISO 17892-12:2018+A2:2022. Soil samples are to be prepared with varying moisture concentrations and then tested to establish their plastic limit, liquid limit, and plasticity index.

Apparatus:

- Casagrande apparatus
- Test specimen containers
- Water
- Scale

Ancillary Apparatus

- Spatula
- Mixing plate
- Rod 3 mm
- Plastic spray bottle

(British Standards Institution, 2022)

This experiment will use the shearbox method, in which the soil specimen is put in a rigid square or circular container (shear box) and shearing is applied by linear movement of one half of the shear box relative to the other. The test will be performed in accordance with BS EN ISO 17892-10:2018 to measure the shear strength of the soil sample as it is widely used to determine shear strength of cohesive soils. The soil sample would be compacted to a certain dry density before being exposed to shear force in a shear box. The shear strength of the soil sample is determined under various normal stresses.

Apparatus:

- Shearbox apparatus
- Weights and balance
- Dial gauge

Ancillary apparatus

- Scale
- Timer
- Cutting tools

Direct Shear Test:

At this point four samples would undergo the direct shear test. One sample would be the control sample and would follow the procedures of the test without plastic added and then three other samples with 2%, 5% and 9% plastic waste replacement.

1. weigh 500 g of air-dried clay soil and mix it with a specified amount of water to reach a certain water content.
2. Place the soil mixture in the shear box and compact it with a compaction tool to a particular height.
3. Attach the proving ring and dial gauge to the shear box in the direct shear apparatus.
4. Put a typical load of 100 kPa and wait 24 hours for the soil to solidify.
5. Start the test by setting the shearing rate to 0.5 mm/min.
6. At regular intervals, record the shear stress and displacement and plot them on a graph.
7. Water is added to attain a specific water content.
8. Do the direct shear test on the clay soil sample as stated above, with the addition of waste plastic by 2%, 5% and 9%. The weight of the plastic materials will be weighed and mixed with 500 g of air-dried clay soil.
9. The information would then be represented graphically.

(British Standards Institution, 2018)

Reference

BSI Standards Publication Geotechnical investigation and testing - Laboratory testing of soil. a.

BSI Standards Publication Geotechnical investigation and testing - Laboratory testing of soil. b.

Geotechnical investigation and testing -Laboratory testing of soil.

, Swelling and Shrinking soils . Available: https://www.bgs.ac.uk/geology-projects/shallow-geohazards/clay-shrink-swell/#:~:text=Clay%20soils%20are%20susceptible%20to,cracks%20appear%20in%20our%20buildings.

GANGWAR, P. and TIWARI, S., 2021. Stabilization of soil with waste plastic bottles. *Materials Today: Proceedings,* **47**, pp. 3802-3806.

LUTENEGGER, A.J., 2019. *Soils and Geotechnology in Construction.* CRC Press.

LYONS, A.(.R.)., 2019. *Materials for architects and builders.* Abingdon, Oxon: Routledge.

NATH, B.D., SARKAR, G., SIDDIQUA, S., ROKUNUZZAMAN, M. and ISLAM, M.R., 2018. Geotechnical Properties of Wood Ash-Based Composite Fine-Grained Soil. *Advances in Civil Engineering,* **2018**, pp. 7 pages.

PATEL, A., 2019. *Geotechnical Investigation and Improvement of Ground Conditions.* Duxford, United Kingdom: Woodhead publishing.

PEDDAIAH, S., BURMAN, A. and SREEDEEP, S., 2018. Experimental Study on Effect of Waste Plastic Bottle Strips in Soil Improvement. *Geotechnical and Geological Engineering,* **36**(5), pp. 2907-2920.

SARAVANAN, R., MURTHI, P., POONGODI, K. and RAJU, A., 2020. A study on the effect of waste plastic strips in the stabilization of clay soil. *IOP Conference Series.Materials Science and Engineering,* **981**(3),.

Wani, I.A., Sheikh, I.M., Maqbool, T. And Kumar, V., (2021). ‘Experimental investigation on using plastic wastes to enhance several engineering properties of soil through stabilization’, Elsevier Ltd, pp. 4571-4574.

Whitlow, R. (2001) *Basic soil mechanics.* 4 edn. Harlow: Prentice Hall.

*I need to work on my reference list