

Assessment of the Impact of Wastewater Sachets on the Bearing Capacity of Phyllitic Soil

Mr. Desmond-Luke M. Anglaaere
PG student, Civil Engineering,
Faculty of Civil Engineering and Mechanics,
Jiangsu University, China.

Dr. Enquan Zhou
Lecturer, Civil Engineering Department,
Faculty of Civil Engineering and Mechanics,
Jiangsu University, China.

Mr. Prince Mashavave
PG student, Civil Engineering,
Faculty of Civil Engineering and Mechanics,
Jiangsu University, China.

Abstract- Soil improvement is a major factor considered when dealing with weak soils for engineering purposes. This report presents the various tests conducted on fiber-reinforced soil with varying fiber content and different aspect ratios. Strips of wastewater sachets were used as a reinforcement material to perform the strength test on the soil. Several Compaction and California Bearing Ratio (CBR) tests were conducted on randomly reinforced soil by alternating the aspect ratio or sizes of plastic strips. The aspect ratios used were 15x10 mm, 15x20 mm and 15x30 mm. The CBR value obtained for the unreinforced soil was 6.85%. The CBR values obtained for the reinforced soil with the plastic fiber of sizes, 15x10 mm, 15x20 mm, and 15x30 mm were 9.31%, 16.91%, and 17.57% respectively. The CBR test results showed that the reinforcement benefit increased with an increase in aspect ratio. Hence, appropriately cut strips of wastewater sachets with optimum sizes would prove useful for soil improvement if mixed with locally available soils in an appropriate quantity. The proposed technique is recommended for embankment/road construction, industrial yards among others.

Keywords: CBR, Compaction, Phyllitic soil, Wastewater sachets, Aspect ratio

INTRODUCTION

Soil is a fundamental material used in every type of construction. The soil used for construction must always be competent enough to withstand the load imposed on it. However, soil types like clay, silt, and organic soils are thought to be of poor quality soils for construction. These varieties of soil are often encountered during construction which is usually excavated and transported to dump sites at a high cost. It has been shown that the geotechnical properties of such soils can be improved for use in construction by numerous techniques such as the addition of Portland cement, lime, bitumen, fly ash, plastic waste, etc. Studies have shown that plastic wastes when mixed with soil behave like fiber-reinforced soil. The mixture of these materials with the soil mass tends to cut back the probabilities of developing potential planes of weakness and the strength, stiffness, ductility, and toughness of the soil are improved to some extent. Phyllitic soils are soils that are derived from the weathering of phyllite (a metamorphic rock). These soils contain predominant clay and silt particles and are classified as weak for construction. Examination of the geotechnical and microstructural characteristics of this soil type was conducted to study its influence on the instability of high slopes indicated failures associated with this type of soil [1]. Recent economic and economic growth has led to the construction of new structures and buildings in many parts of the world. During these constructions, there is the possibility of encountering weak soils along the road corridor which may have to be completely removed or improved upon. In Ghana, wastewater sachets are often littered around by individuals. These end up choking gutters and polluting the environment. These choked gutters cause floods during a heavy downpour, therefore, posing threats to human life. Also, the increase in population has led to the production of more plastic products for the satisfaction of human needs hence the pollution by plastic waste is on the rise. To ensure economic and eco-friendly construction, many pieces of research have been conducted to explore the possible ways waste materials can be useful in construction. Sing and Mittal [2] Researched the use of plastic strips for soil stabilization. Different contents of the Strips of different proportions were added to the soil. The optimum percentage of plastic strips needed for stabilization was obtained at the end of the experiment. Raw plastic bottles were used by [3,4] to stabilize the soil. They studied its effect on the mechanical properties of the soil. A plate loading test and a California bearing test were conducted. The result produced a significant effect on the enhancement of soil strength. Furthermore, there is a wide range of plastics being used for the stabilization process. The use of a Highly Dense Polyethylene (HDPE) plastic in the stabilization process yielded positive results [5,6],[7]. The addition of optimum quantities of the plastic strips improved the strength properties of the soil. Sing et al [8] Conducted an experiment using scrape rubber tire to stabilize clay soil. A percentage of 0.05%, 0.06%, 0.7%, 0.8%, 0.9% and 1% of tire chips were mixed in clay for the conduction of a CBR test. There were improvements in the shear strength, ductility, toughness, and isotropy in the soil.

In this research, wastewater sachets will be used as the plastic strips. A series of CBR tests will be conducted with varying percentages of the plastic strips. The result will reveal the significance of the use of plastics in the stabilization of soil. The use of waste materials for the improvement of soil has been on the rise. This phenomenon came up as the need to employ ways of dealing

with challenges caused by waste materials. The control of plastic waste has been a major ecological challenge due to its biodegradable nature hence needs effective management interventions. The engineering behavior of soil reinforced by plastic strips was noted to be significantly improved [9]. Dachowski [10] investigated the use of waste materials in the construction industry. Foam glass and high-impact polystyrene were used as modifiers of the basic construction materials. The focus of the research was to analyze the compressive strength, water absorption, bulk density, and the construction of structural material. Based on the studies, the additives had a significant influence on the properties of cement mortars. It was concluded that the use of high-impact polystyrene and foam glass can be considered as a useful way of utilization waste. Further analysis of the use of plastics by [11,12] and [13,14] proved the effective use of tire scraps in the stabilization process. The addition of different proportions of the tire scraps improved the strength properties of the soil at an optimum quantity of the tire scraps. More so, Kalumba and Chebet [15] evaluated the use of shopping bags in stabilizing sandy soil. The shopping bags waste were cut into strips of aspect ratios 15 mm x 6 mm and 45 mm x 18 mm and added to soil at a constant proportion of 0.3% by weight. A number of direct shear tests were conducted on the soil and plastic mixture which resulted in an improvement of the shear strength property of the soil. Polyethylene terephthalate fibers extracted from recycled plastic bottles were mixed with cement to improve the engineering properties of uniform fine sand [16]. The fibers were cut into varying lengths up to 36 mm and cement was from 0% to 7% by weight. The results indicated a significant improvement in the peak and ultimate strength of both cemented and uncemented soil and also cut down the brittleness of the cemented sand. Plastic wastes have been incorporated into many recent construction projects through material stabilization. The use of waste rubber in construction includes the stabilization of materials such as cement-based concrete, asphalt concrete, and granular materials for earth structures [17]. An investigation was conducted by Muntohar [18] to analyze the effect of plastic waste on the Strength of Lime-Rice Husk Ash stabilized clay soil. In this research, the clay was already stabilized by lime and rice husk. However, plastic fibers were added to investigate its effect on the compressive and split strength of the soil. This resulted in a significant increase in the unconfined compressive strength and tensile-split strength of the clay soil. Most researches conducted using polythene fibers focused more on the proportion of the strips and less on the aspect ratio of the strips. This research seeks to elaborate on the use of plastic strips with different aspect ratios.

This paper presents a study on the use of wastewater sachets, a popular plastic product used in Ghana, to improve upon the quality of phyllitic soil for construction. Phyllitic soils are weak soils that are predominately composed of silt and clay. The use of the wastewater sachet for such a purpose would also have a positive impact on the environment as this would reduce pollution to some extent. This paper, therefore, seeks to analyze the influence of wastewater sachets in the stabilization of phyllitic soil.

MATERIALS AND METHODOLOGY

Phyllitic Soil: This experiment was conducted using phyllitic soil obtained from a test pit. A test pit was dug at a depth of 1.5 meters (m) to obtain fresh soil from the ground void of debris or any form of impurities.

Wastewater sachets: The water sachets were collected from recycling bins for this experiment. This material is added to soil in a form of strips with different aspect ratios.

Various tests were carried out on the soil samples based on the BS code 1377 of 1990 to obtain the required data for analysis. Among the tests conducted were the index property test and the strength test.

The index property test include;

- Moisture Content Determination.
- Atterberg's Limit Test.
- Specific Gravity Test.
- Sieve Analysis.

The strength test conducted include;

- Compaction Test.
- California Bearing Ratio Test.

The main focus of the test is to determine the effect of the wastewater sachet on the strength of the soil sample. A compaction test was conducted according to the ASTM code to determine the maximum dry density and optimum moisture content of the soil.



Figure 1a. Pulverized water sachets



Figure 1b. Soil mixed with waste water sachet

RESULTS

Atterberg's Limits Test

At the end of the test, a liquid limit chart was generated with the number of blows plotted against moisture content. The plotted values are shown in Table 1. From the chart, (Fig 2), the liquid limit was determined and used to calculate the plasticity index. With the plasticity index, the inference was made from the plasticity chart as shown in Fig 3.

Table 1 Plotted Values for Liquid Limit

NUMBER OR BLOWS	MOISTURE CONTENT
41.0	22.1
32.0	21.4
22.0	22.1
11.0	26.3

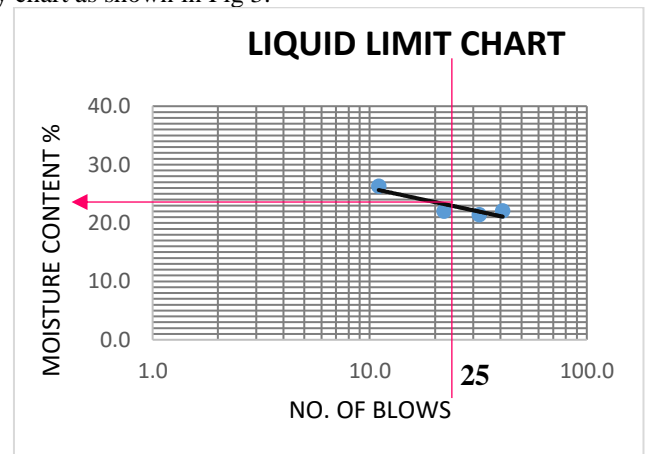


Fig 2. Liquid Limit Chart

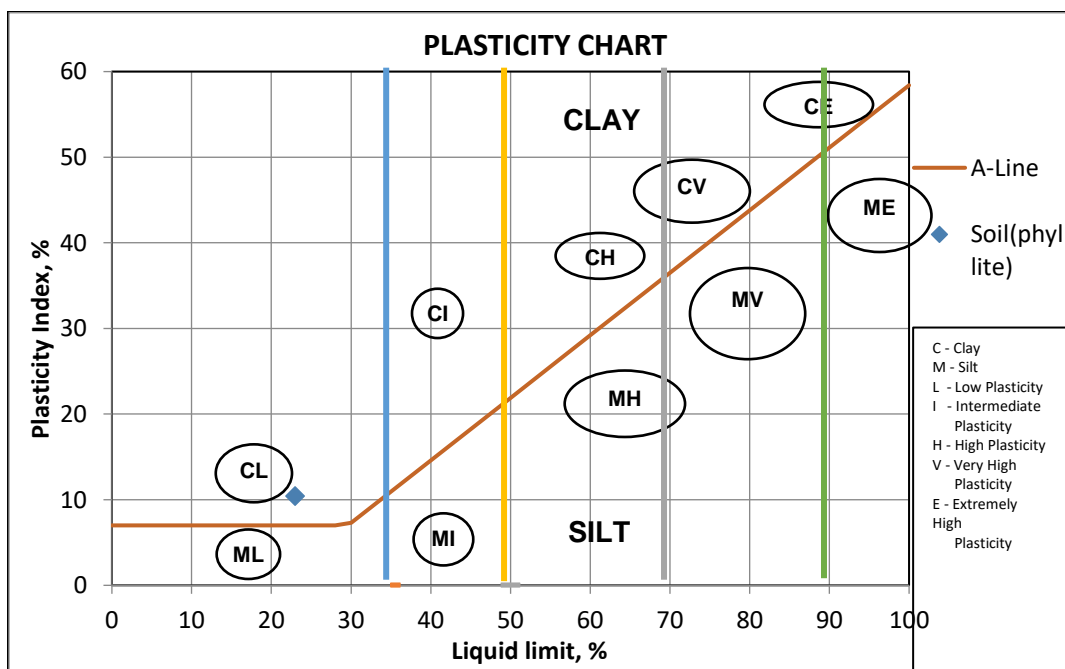


Fig 3 Plasticity Chart (after Casagrande 1948 [19]).

Specific Gravity Test

From the specific gravity test, the average specific gravity of the soil was obtained from the results shown in Table 2

Table 2 Results for Specific Gravity Test

Specimen ID	Phyllite	
Pycnometer Bottle No.	C	B
Mass of empty Pycnometer + stopper (m1)	21.8	20.4
Mass of empty Pycnometer + soil (m2)	31.8	30.4
Mass of empty Pycnometer + soil + Liquid (m3)	66.4	66.8
Mass of empty Pycnometer + Liquid (m4)	61	59
Specific Gravity, $\rho_s = \frac{(m_2 - m_1)}{(m_4 - m_1) - (m_3 - m_2)} \times \rho_L$	1.78	3.71
Average Specific Gravity	2.75	

At the end of the test, the obtained specific gravity was used to classify the soil according to the specific gravity ranges

Compaction

From the compaction test, a graph of dry density against water content was plotted.

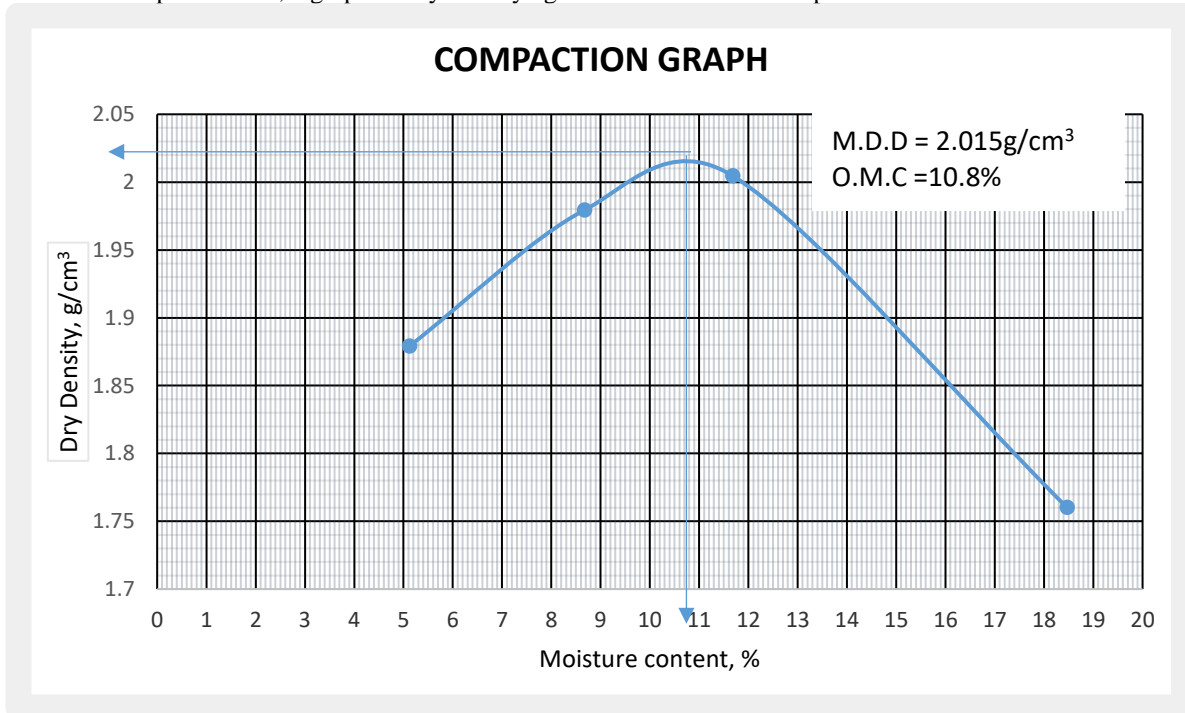


Fig 4 Compaction Curve for the Phyllitic Soil.

At the end of the test, a maximum dry density of 2.015g/cm³ and an optimum moisture content of 10.8% were obtained.

CBR Test

The test was conducted on the same soil first with no plastic strip followed by soil with different aspect ratios of plastic strip thus (15x10mm), (15x20mm), and (15x30mm). The results are shown below. Also, a load penetration curve is illustrated in figure

Table 4 Phyllitic Soil 0% Plastic Strip

PEN. (mm)	READING	LOAD (kN)	CBR %
0.5	5.0	214.0	
1.0	8.0	342.4	
1.5	11.2	479.4	
2.0	14.5	620.6	
2.5	18.0	770.4	5.8
3.0	21.1	903.1	
3.5	24.2	1035.8	
4.0	27.0	1155.6	
4.5	30.0	1284.0	
5.0	32.0	1369.6	6.9
5.5	35.0	1498.0	
6.0	48.0	2054.4	

Table 5 Phyllitic Soil with 0.5% Plastic Strip of AR (15x10mm)

PEN. (mm)	READING	LOAD (kN)	CBR %
0.5	4	171.2	
1.0	10	428	
1.5	14.8	633.44	
2.0	19.2	821.76	
2.5	23.8	1018.64	7.72
3.0	28	1198.4	
3.5	32	1369.6	
4.0	36	1540.8	
4.5	39.8	1703.44	
5.0	43.5	1861.8	9.31
5.5	47	2011.6	
6.0	50.4	2157.12	

Table 6 Phyllitic Soil with 0.5% Plastic Strip of AR (15X20mm)

PEN. (mm)	READING	LOAD (kN)	CBR %
0.5	2.0	85.6	
1.0	7.0	299.6	
1.5	16.0	684.8	
2.0	29.0	1241.2	
2.5	41.0	1754.8	13.3
3.0	49.0	2097.2	
3.5	55.0	2354.0	
4.0	61.0	2610.8	
4.5	70.0	2996.0	
5.0	79.0	3381.2	16.9
5.5	86.2	3689.4	
6.0	91.0	3894.8	

Table 7 CBR results for Phyllitic Soil with 0.5% Plastic Strip of AR (15X30mm)

PEN. (mm)	READING	LOAD (kN)	CBR %
0.5	24.0	1027.2	
1.0	31.0	1326.8	
1.5	37.0	1583.6	
2.0	43.0	1840.4	
2.5	48.0	2054.4	15.6
3.0	53.0	2268.4	
3.5	58.0	2482.4	
4.0	64.0	2739.2	
4.5	72.0	3081.6	
5.0	82.1	3513.9	17.6
5.5	89.0	3809.2	
6.0	95.0	4066.0	

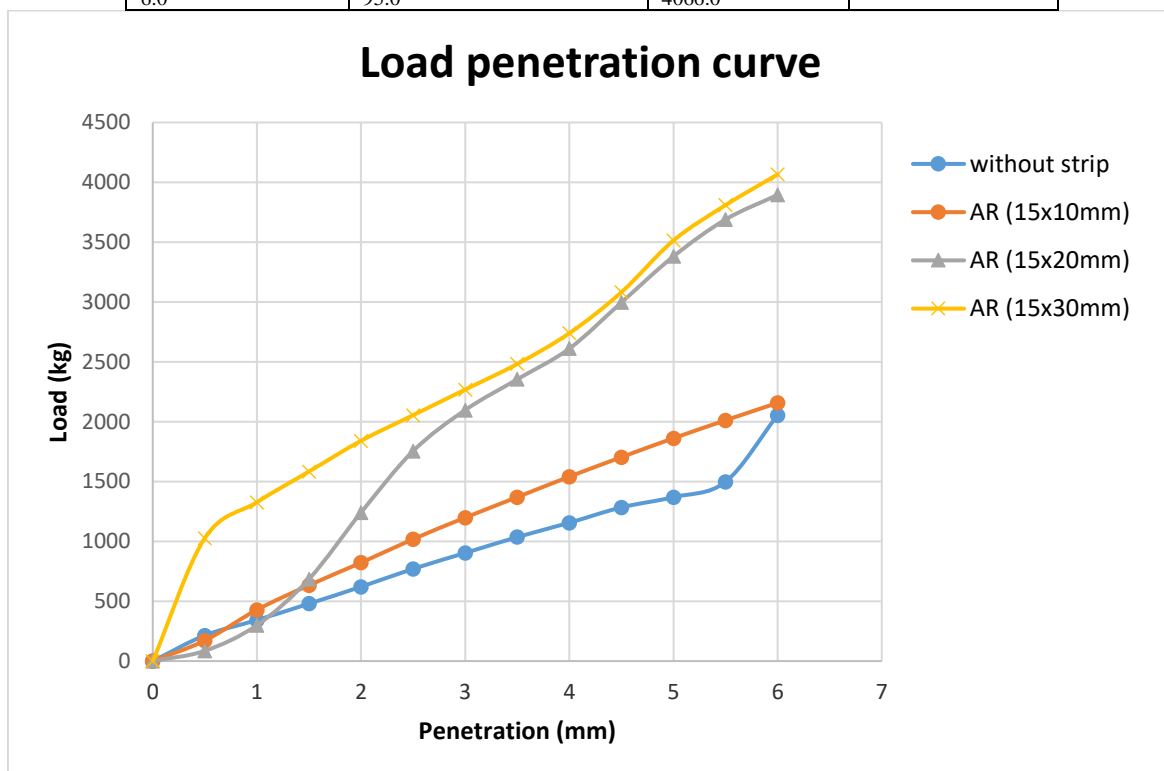


Figure 5 CBR Curves for Various Aspect Ratios (AR) of Plastic Mixed with the Soil.

DISCUSSION OF RESULTS

From the index property test conducted, the soil has a specific gravity of 2.75 which from the specific gravity chart indicates it contains silt and clay. It has a liquid limit of 23.0, a plastic limit of 12.6, and a plasticity index of 10.4. According to the plasticity chart, the soil was classified as "CL" (clayey with low plasticity). The maximum dry density and optimum water content as determined by the compaction test were 2.015g/cm³ and 10.8%. This means that beyond the optimum moisture content the dry unit weight of the soil would reduce.

After completion of each CBR test, the specimen was dissected and the strips were examined. Many of the strips showed elongation, thinning, and a clear impression of soil particles. Apparently, as the soil sheared during penetration, the strips fixed in the soil by friction, elongated, and together provided strength against the deformation. The CBR test was conducted with varying aspect ratios at the same strip content thus 0.5%. The results indicated an increase in the piston load upon the uniform mixture of the plastic strips with the soil. It is also evident from the results that the inclusion of waste plastic increased the CBR value appreciably. At 0% plastic strip content, the CBR value of the soil at 2.5 mm and 5.0 mm penetration was found to be 5.84% and 6.85% respectively. The CBR value was increased to 7.72% and 9.31% respectively when the soil was reinforced with 0.5% waste plastic strips having an aspect ratio (15x10 mm). Further increase in aspect ratio without changing the strip content again enhanced the CBR value to 13.29% and 16.91% for (AR: 15x20 mm) and CBR values of 15.56% and 17.57% for (AR: 15x30 mm) respectively. The maximum CBR value obtained was 15.56% and 17.57% respectively when 0.5% waste plastic strip content having an aspect ratio (15x30 mm) was mixed with the soil. This reveals that at AR (15x30 mm) for 0.5% strip content gives us the maximum bearing strength.

CONCLUSIONS

The possibility of reinforcing soil with strips of plastic waste was investigated in this study. Strips of water sachet wastes were mixed with soil and tested to determine CBR values; maximum load-carrying capacity of subsoil. The result analysis showed that reinforcing soil with waste plastic strips enhances its strength. Inferring from the results obtained, the following conclusions were made.

- The CBR value obtained without plastic strips was 6.85%
- The CBR value obtained while using a plastic strip of Aspect Ratio (AR) of 15x10 mm was 9.31%
- The CBR value obtained while using a plastic strip of Aspect Ratio (AR) of 15x20 mm was 16.91%
- The CBR value obtained while using a plastic strip of Aspect Ratio (AR) of 15x30 mm was 17.57%
- The addition of the plastic strips to local soil increases the CBR.
- The maximum improvement in CBR is obtained while using 0.5% of plastic strips having an aspect ratio (15x30 mm).
- The reinforcement benefit increases with an increase in Aspect Ratio (AR).

The reinforcement benefit increased with an increase in AR, therefore, I can conclude that appropriately cut strips of wastewater sachets with optimum sizes would prove useful for soil improvement if mixed with locally available soils in an appropriate quantity.

RECOMMENDATION

I recommend that further studies must be conducted;

- To optimize the size and shape of strips and increasing the percentage content.
- To assess the durability and aging of the strip.
- To further explore the engineering properties of the soil that can be enhanced.

REFERENCE

- [1] M. Saberian and M. A. Rahgozar, "Geotechnical properties of peat soil stabilised with shredded waste tyre chips in combination with gypsum, lime or cement," *Mires Peat*, vol. 18, 2016, doi: 10.19189/MaP.2015.OMB.211.
- [2] K. Singh and A. Mittal, "Soil Stabilisation Using Plastic Waste," *Lect. Notes Civ. Eng.*, vol. 32, pp. 91–96, 2019, doi: 10.1007/978-981-13-7017-5_10.
- [3] S. Saravanan and B. J. Ravindraraj, "Soil stabilisation using raw plastic bottles," *Int. J. Civ. Eng. Technol.*, vol. 9, no. 4, 2018 pp. 812–815.
- [4] R. B. Kassa, T. Workie, A. Abdela, M. Fekade, and M. Saleh, "Soil Stabilization Using Waste Plastic Materials," vol. D, pp. 55–68, 2020, doi: 10.4236/ojce.2020.101006.
- [5] M. Neopaney, K. Wangchuk, S. Tenzin, Ks. Chamberlin, and A. Professor, "Stabilization of Soil by Using Plastic Wastes," *Int. J. Emerg. trends Eng. Dev.*, vol. 2, no. 2, 2012, pp. 461–466.
- [6] T. Divya *et al.*, "Experimental Analysis of Stabilization of Soil by using Plastic Waste," no. 2, 2015, pp. 371–376.
- [7] A. K. Choudhary, J. N. Jha, and K. S. Gill, "a Study on Cbr Behavior of Waste Plastic Strip Reinforced Soil," *Emirates J. Eng. Res.*, vol. 15, no. 1, 2010, pp. 51–57.
- [8] S. Singh, U. Dhiman, and R. Sharma, "Soil Stabilization using Scrap Rubber Tyre," *Int. Res. J. Eng. Technol.*, 2017, pp. 3157–3161.
- [9] P. Bhattarai, B. Kumar, K. Santosh, T. C. Manikanta, and K. Tejeswini, "Engineering Behavior of Soil Reinforced With Plastic Strips," *Int. J. Civ. , Struct. , Environ. Infrastruct. Eng. Res. Dev.*, vol. 3, no. 2, 2013, pp. 2249–6866.
- [10] R. Dachowski and P. Kostrzewa, "The Use of Waste Materials in the Construction Industry," in *Procedia Engineering*, 2016, vol. 161, pp. 754–758, doi: 10.1016/j.proeng.2016.08.764.
- [11] S. Akbulut, S. Arasan, and E. Kalkan, "Modification of clayey soils using scrap tire rubber and synthetic fibers," *Appl. Clay Sci.*, vol. 38, no. 1–2, pp. 23–32, Dec. 2007, doi: 10.1016/j.clay.2007.02.001.
- [12] J. S. Yadav and S. K. Tiwari, "Effect of waste rubber fibres on the geotechnical properties of clay stabilized with cement," *Appl. Clay Sci.*, vol. 149, 2017, doi: 10.1016/j.clay.2017.07.037.
- [13] Q. Ma, Q. Deng, J. Mou, S. Yang, and X. Zhang, "Large-Scale Direct Shear Test on Scrap Tire Strip Reinforced Brick Powder," *Adv. Civ. Eng.*, vol. 2019, 2019, doi: 10.1155/2019/6046037.

- [14] M. D. V Zutting, "Soil Stabilization by using Scrap Tire Rubber," vol. 9, no. 06, 2020, pp. 1382–1388.
- [15] D. Kalumba and F. C. Chebet, "Utilisation of polyethylene (plastic) shopping bags waste for soil improvement in sandy soils," *18th Int. Conf. Soil Mech. Geotech. Eng. Challenges Innov. Geotech. ICSMGE 2013*, vol. 4, 2013, pp. 3223–3226.
- [16] N. C. Consoli, J. P. Montardo, P. D. M. Prietto, and G. S. Pasa, "Engineering Behavior of a Sand Reinforced with Plastic Waste," *J. Geotech. Geoenvironmental Eng.*, vol. 128, no. 6, pp. 462–472, Jun. 2002, doi: 10.1061/(asce)1090-0241(2002)128:6(462).
- [17] A. Mohajerani *et al.*, "Recycling waste rubber tyres in construction materials and associated environmental considerations: A review," *Resources, Conservation and Recycling*, vol. 155. Elsevier B.V., 01-Apr-2020, doi: 10.1016/j.resconrec.2020.104679.
- [18] a. S. Muntohar, "Influence of Plastic Waste Fibers on the Strength of Lime-Rice," *Civ. Eng. Dimens.*, vol. 11, no. 1, 2009, pp. 32–40.
- [19] "Casagrande, A. (1948) Classification and Identification of Soils. Transactions of the American Society of Civil Engineers, 113, 901-930. - References Scientific Research Publishing." [Online]. Available: [https://www.scirp.org/\(S\(351jmbntvnsjtl1aadkposzje\)\)/reference/ReferencesPapers.aspx?ReferenceID=2205851](https://www.scirp.org/(S(351jmbntvnsjtl1aadkposzje))/reference/ReferencesPapers.aspx?ReferenceID=2205851). [Accessed: 23-Dec-2020].