JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A Green Approach to Soil Improvement: PET Waste and Its Influence on Shear and Permeability Values

[1]Imran Hussain
[1]Assistant Professor (G.F.),
Civil Engineering Department, College of Technology and Engineering Udaipur (Rajasthan) India

ABSTRACT: Soil reinforcement in engineering involves strengthening soil through methods such as mechanical compaction and the incorporation of plastic waste materials. The use of alternative techniques to enhance soil strength is environmentally beneficial, especially when it involves recycling discarded waste like plastic products. This modern approach to soil reinforcement addresses societal challenges, reduces waste accumulation, and repurposes discarded materials into valuable resources. Thus, utilizing waste plastic bottles to improve soil quality represents an economically viable solution, given the limited availability of high-quality soil for construction. The primary objective of this research paper was to explore the potential use of plastic bottle waste for stabilizing medium-compressible clayey soils. The study systematically conducted experiments, employing diverse sizes of plastic waste and various substitution ratios. A comprehensive set of tests, including both index and mechanical properties, was carried out on soil samples from the Sisarma area in the Udaipur region. The results unequivocally demonstrate that incorporating plastic waste, up to a 2% substitution rate, positively impacts the permeability and shear strength properties of the soil. It is advisable to use plastic waste with dimensions not exceeding 10mm for optimal outcomes. This research provides valuable insights into the advantages and limitations of using plastic waste for soil reinforcement.
Keywords: Index properties, mechanical properties, Permeability, Direct shear Test, Soil reinforcement

I INTRODUCTION: - Soils with desirable engineering properties serve as essential fill materials for various engineering applications, including backfilling in highway embankments, road layers, and building foundations. However, in some instances, finding suitable soils can be challenging, leading to the use of alternative soil types. Unfortunately, these alternatives may possess undesirable engineering properties, such as poorly graded soil, which is susceptible to water and wind action and poses challenges in compaction. Sandy soil, for instance, is unsuitable for roadbed construction, as highlighted by Al-Taie (2020). Therefore, utilizing such substitutes necessitates enhancing the geotechnical properties of poorly graded soil. This enhancement involves improving mechanical parameters like compaction and shear strength to meet the required engineering standards. Various additives, including silica fume, cement kiln dust, fly ash, cohesive admixtures, and treated coir fiber, can be employed for enhancing the geotechnical properties of soil (Dutta, n.d., 2016; Awoyera P. O., 2020; Al-Taie, 2020).

Environmental conservation and the preservation of rapidly depleting natural resources are global challenges (Ilieş, n.d.). Recognizing this, the world is shifting towards sustainable development, with these considerations now integral to the nation-building policies of every country. This study addresses a current issue faced by the state of Rajasthan, namely, the safe disposal of plastic waste material.

1.1 SOIL REINFORCEMENT TECHNIQUES

Various methods of soil reinforcement are employed, each with its unique impact on enhancing in-situ soil. The effectiveness of these methods can vary not only within a specific technique but also when compared to others. This variability arises due to the diverse range of soil types, each exhibiting distinct behaviors in response to different stabilizers. Some of the noteworthy methods include:

- Mechanical Reinforcement: Involves the use of mechanical elements or devices to enhance the strength and stability of soil.
- Cement Stabilization: Utilizes cement as a stabilizing agent to improve the mechanical properties of soil, enhancing its load-bearing capacity.
- Lime Stabilization: Incorporates lime into the soil to modify its properties, improving factors like plasticity, strength, and durability.

- Chemical Stabilization: Involves the use of various chemical agents to alter the composition and behavior of soil, enhancing its engineering properties.
- Thermal Stabilization: Applies heat or thermal treatment to soil to induce changes in its structure and properties, contributing to stabilization.
- Bitumen Stabilization: Utilizes bituminous materials to enhance the engineering characteristics of soil, particularly in road construction and pavement applications.

Each of these methods offers specific advantages and is chosen based on the characteristics of the soil and the desired engineering outcomes for a particular project.

1.2 SCENARIO OF PLASTIC WASTE

1.2.1 Generation of Plastic waste

In India, a substantial amount of plastic waste is generated on a daily basis, with approximately 25,940 tonnes produced each day, as reported by the Central Pollution Control Board (CPCB) after studying 60 major cities. The combined plastic waste production in these cities amounts to 4,059 tonnes per day. Delhi holds the top position among these cities, being the largest contributor to plastic waste generation, followed by Chennai, Mumbai, Bangalore, and Hyderabad. This highlights the significant challenge posed by plastic waste management in urban centers across the country.

1.2.2 Types of Plastic waste

The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 in response to the encouragement of recyclers across the country. There are several types of plastics classified under this coding system:

a. Polyethylene Terephthalate [PETE or PET]
b. High-Density Polyethylene [HDPE]
c. Polyvinyl Chloride [PVC]
d. Low-Density Polyethylene [LDPE]
e. Polypropylene [PP]
f. Polystyrene or Styrofoam [PS]
g. Miscellaneous plastics [Encompassing polycarbonate, polylactide, acrylic, acrylonitrile butadiene, styrene, fiberglass, nylon, etc.]

Plastics are generally categorized into two types:
Thermoplastics: Thermoplastics, or Thermo-softening plastics, soften upon heating and can be molded into the desired shape. Examples include PET, HDPE, LDPE, PP, PVC, PS, etc.
Thermosets: Thermoset or thermosetting plastics strengthen upon heating but cannot be remolded or recycled. Examples include Sheet Molding Compounds (SMC), Fiber Reinforced Plastic (FRP), Bakelite, etc.

1.2.3 Effects of Plastic Waste on Environment

Plastic, being a non-decomposable material with an extremely slow rate of decomposition, tends to accumulate in the environment, posing adverse effects on ecosystems. Classified based on size, plastic pollutants can be categorized into micro and macro pollutants. Due to their economic viability and durability, humans produce plastic at a high rate. The chemical structure of plastic makes it resistant to natural decomposition processes, rendering it almost non-degradable. Some harmful effects of plastic waste include:

- Groundwater Contamination: When plastic bags are left in the soil, they slowly release toxic compounds that can reach the groundwater table. Consumption of this contaminated water can lead to severe health issues.
- Clogging of Sewage Systems: Plastic bags, especially in urban areas, can clog sewage systems, causing significant harm to the environment. This clogging not only inconveniences people in the affected area but also leads to water overflow, potentially damaging buildings and properties. Moreover, pollutants collected by the excess water can spread over a wide area.
- Ocean Pollution: Disposal of plastic waste into the ocean releases toxic chemicals, endangering aquatic species and sometimes leading to their extinction.
- Wildlife Loss: Plastic waste consumption by animals results in severe health problems. Animals that ingest plastic may suffer from intestinal obstructions, leading to prolonged and painful deaths. Some animals die from malnutrition as plastic decomposes very slowly and fills their stomachs.
- Aesthetic Damage: Plastic waste contributes to the loss of natural beauty in ecosystems, ruining their aesthetic appearance. This visual pollution affects the overall quality of the environment.

1.2.4 Plastic Waste Management

Waste plastic recycling in India faces organizational challenges, with only approximately 60% of the collected and sorted plastic being effectively recycled. To address this issue, a national plastic waste management council task force has been established through collaboration between the Government of India, the Ministry of Environment, the Department of Petroleum and Chemical, the Ministry of Union Affairs, and various plastic manufacturing groups and associations. Their primary objective is to implement effective recycling and management strategies for plastic waste.

In India, municipal solid waste contains around 4% plastic waste, posing a significant environmental hazard. Irresponsible burning of polythene bags for disposal releases high amounts of toxic gases such as carbon monoxide, chlorine, sulfur dioxide, and nitrogen dioxide.

Several regulations and legislations have been introduced in India to manage plastic waste effectively:

- The Ministry of Environment established a nationwide plastic waste management task force, initiating a strategy and action program for managing plastic waste in the country.
- The Bureau of Indian Standards (BIS) issued guidelines on plastic waste recycling, covering practices like collecting plastic waste and upgrading sorting techniques. The Ministry of Environment, in collaboration with BIS, has implemented practices for the reuse of recycled plastic waste when appropriate.
- The Prevention of Food Adulteration Department issued directives to food caterers, mandating the use of food-grade plastic for serving food. Specific rules outline the requirements for food-grade plastic to ensure safety when in contact with food.
- PET manufacturers formed a national association to oversee the organized collection and recycling of PET bottles, contributing to more sustainable practices in plastic waste management.

1.2.5 IMPORTANCE OF RESEARCH STUDY

Rajasthan is currently facing a significant challenge with the increasing generation of plastic waste, as highlighted in a report from the Government of India under the Swachh Bharat Mission. In response to this concern, there is an initiative underway to explore an alternative solution for the disposal of plastic waste, with a specific emphasis on its role in soil stabilization. The primary objective is to conduct a comprehensive study focusing on the utilization of plastic waste to enhance soil properties. The outcomes of this research are expected to play a crucial role in integrating plastic waste into the planning and construction of various civil engineering projects, encompassing pavements and machine foundations. This approach seeks to address the environmental issues associated with plastic waste while simultaneously contributing to the enhancement of soil quality for construction purposes.

II. LITERATURE REVIEW

Al-Taie et al. (2020) carried out study on "Utilization of Depolymerized recycled polyethylene Terephthalate in impring poorly graded soil". They have showed with plastic waste in the form of powder (using depolymerization) is mixed with different proportion of reinforced soil. They have showed the increase in Confined Compression of soil, increase in angle of internal friction and reduced the maximum vertical contractive displacement of soil.

Tomar et al. (2020) the main objective of this research is to look over the ideal combination of Nano Silica (NaSiO2) and Polypropylene fiber (PP) with clay soil. The physical and mechanical properties such as liquid limit (LL), plastic limit (PL), maximum dry density (MDD) and unconfined compressive Strength (UCS) are researched with normal soil, the soil with Nano Silica (NaSiO2) and combination of soil with Nano Silica (NaSiO2) and polypropylene fiber (PPF). The resilience test is performed to understand the strength of reinforced soil by analyzing alternate wet and dry Cycles Also, Scanning Electron Microscopy (SEM) test had been carried out and sculpture are obtained to understand micro-structural mitigation towards combination of NanoSiO2 and polypropylene fiber. The different combinations of Nano Silica (NaSiO2) at different variation of 1.0%, 3.0%, 5.0% and 7.0% are used in incorporation with polypropylene fiber is used in different proportion such as, 0.1%, 0.4%, 0.7%, 1%, and 1.3c

Carvalho et al. (2019) carried out an evaluation of resilient behavior of clayey soil with polyethylene terephthalate (PET) insertion for application in pavement base. In this study, they analyzed the geotechnical performance of the material, physical tests, compaction and Cyclic Triaxial tests (Resilient Modulus) were carried out on pure soil as well as on the mixture of soil and PET flakes in weight percentages of 3, 5 and 7 %. They had used 2 mm size PET flakes strip throughout his research. They had used computer program SisPav (Franco, 2007) to perform a mechanistic-empirical design for a typical pavement structure with parameters obtained for the mixtures. The results indicated that the insertion of PET influences the mechanical behavior of the soil. They had founded that resilient modulus increases, with respect to that of pure soil, for mixtures with the lowest content of PET (3%). For tests with higher contents of PET flakes, the Resilient Modulus decreases. There research concluded that the clayey soil mixed with polyethylene terephthalate flakes can be used as an alternative material for pavements base, as long as a low content of flakes is used.

Singh et al. (2019) carried out experimental investigation on stabilization of fine grained soil using plastic waste. Samples are prepared by mixing with four different plastic waste contents (0, 0.5, 1, and 1.5% of weight of dry soil). Variations in compaction characteristics and unconfined compressive strength are investigated as per Indian standard experimental procedures. Percentage decrease/increase in the stated parameters is computed with respect to their untreated value. Study shows that plastic waste additive increases maximum dry density, optimum moisture content, and unconfined compressive strength to some extent. The plastic waste cut into strips form of size 5 mm× 3 mm. In this study they had suggested conclusion that parameter that drastically improves with addition of plastic waste is Unconfined Compressive Strength (UCS) of soil. Addition of 0.5–1% plastic waste increases the UCS by 3– 13% compared to that of untreated soil.

2.2 SUMMARY OF LITERATURE REVIEW

The existing literature reviews have extensively covered experimental studies on soil reinforcement. However, researchers have noted that stabilization has emerged as a major concern in geotechnical engineering. Soil plays a crucial role in the foundation of any infrastructure, serving purposes in construction, pavements, and bricklaying, contributing to the overall strength of structures. The studies reviewed advocate the use of natural industrial waste materials for soil stabilization, providing a dual solution by improving soil properties and addressing the problem of waste disposal.

Based on the collective findings, the researchers concluded that the controlled use of plastic waste enhances the mechanical properties of soil. Soil reinforcement with plastic waste is identified as a highly effective method for the systematic disposal of plastic waste, offering a sustainable approach to address both soil stability concerns and environmental waste management.

III. MATERIALS

3.1 SOIL: The key component employed in embankment construction and highway subgrade is the soil. The performance of pavements, particularly flexible pavements, is intricately linked to the type and properties of the subgrade soil. In this study, soil samples were obtained from Sisarma, located approximately 10 km away from Maharana Pratap University. The categorization of soil was conducted in accordance with IS-1498 [1970], which outlines the "Sorting and recognition of soils for extensive engineering purposes." The soil was then subjected to a 425-micron sieve, and the portion that passed through the sieve was collected for testing.

To assess the distribution of particle sizes in a given dry soil sample, a particle size analysis, or instinctive analysis, was performed. This analysis involves the separation of soil into different size fractions and is conducted in two phases: (1) Sieve analysis for coarse-grained soils and (2) Accumulation analysis or Wet Intensive analysis for fine-grained soils.

3.2 Plastic Waste

The waste plastic strips from bottles or PET waste were sourced from a local industry, specifically Tammana Polypet in Udaipur. These plastic strips had aspect ratios of one and two. The study utilized waste plastic bottle strips with various dimensions (BxL), including 1x1, 1x2, 2x2, 2x4, 4x4, 4x8, 6x6, 6x12, 8x8, 10x10, and 12x12 in millimeters. These plastic strips were incorporated into the soil in different proportions by weight. The study considered strip percentages of 0%, 0.5%, 1.0%, 1.5%, and 2% concerning the dry weight of the soil.

3.3 Water

Potable water is used throughout the study and it is free from any impurities of salt, organic content etc.

IV METHODOLOGY:

4.1 Direct Shear Test -IS 2720-13 (1986)

The shear strength of soil refers to its resistance to deformation, and when this strength reaches its limiting value, shear deformation occurs, leading to the failure of the soil mass. Shear stress is determined by the ratio of shear force to the area of the specimen, and the relationship between shear force and normal stress is graphically represented. The values of internal frictional and cohesion of the soil are crucial outputs from this test and are essential for various engineering designs, including those for retaining walls, sheet piling, subgrade design, and foundations.

The Direct Shear test is conducted using an apparatus comprising a square divided into two halves. The soil specimen, housed in the box, undergoes a constant normal load while an increasing horizontal force is applied to one section of the shear box. This force induces shear failure along the junction between the box sections. Both shear force and normal load are directly measured. The rate of strain is adjusted by the speed of the applied horizontal force. The loading unit features V-strips supporting the shear box housing, suitable for specimens sized 60x60x25mm. The recalibrated load yoke assists in counterbalancing the loading system, and it includes a direct and through lever system for applying a normal load up to 3 kg/cm2 capacity. Fixtures for the proving ring, brackets for holding consolidation and strain dial gauges are also provided. The lead screw, connected to the shear box housing, facilitates the application of shear stress.

The test procedure involves placing the soil in the shear box at its optimum moisture content and maximum dry density. The shear box, assembled from two independent parts, experiences a constant normal load (σ) to determine specific values of cohesion (c) and angle of internal friction (ϕ). The horizontal or shearing load is incrementally increased until the failure point is reached. The load at failure, when divided by the area, provides the shear strength (τ) for that specific normal load.

The equation used for sum up:

$$\tau = c + \sigma * \tan(\upsilon)$$

After persisting, the trial for inconsistent normal loads (ς) we procure a graph, which is a straight line with slope equal to angle of internal friction (υ) and intercept equivalent to the cohesion (c).

4.2 Permeability test -IS 2720-17 (1986)

This test used to obtain the coefficient of permeability of a soil. This test performed by two methods, Constant head method and Falling head method. This attribute is much useful in resolving problems involving yield of water bearing strata, seepage across earthen dams, firmness of earthen dams, and embankments of canal bank pretentious by seepage, settlement etc.The permeability test carried out with apparatus, Glass stand pipes for falling head (variable head) test arrangement, varying in diameter from 5 to 20 mm, suitably mounted on stand or otherwise fixed on wall. Appropriate water reservoir competent for contributing water to the permeameter under constant head for trial assessment. Other apparatus, such as IS sieves, mixing pan, graduated cylinder, metre scale, stop watch, 75micron wire gauge, thermometer, and a source of de-aired water.A 2.5-kg sample shall be taken from a thoroughly mixed air-dried or oven-dried material which has been obtained in accordance with IS: 2720 (Part 1)-1983. The moisture content of the 2.5 kg sample shall be determined. The sample shall be placed in an airtight container. The quantity of water to be added to the stored sample to give the desired moisture content shall be computed and spread evenly over the sample, and after thoroughly mixing, the material shall again be placed in the storage container. The moisture content of the sample shall again be determined and the entire process repeated until the actual moisture content is within 0.5 percent of that desired.

Coefficient of permeability for a constant head test is given by

$$K = qL/Ah$$ Where K=

Coefficient t of permeability in cm/Sec.

q = Discharge cm^3/Sec.

L = length of specimen in cm A = Cross sectional area in cm^2

h= Constant head causing flow in cm

V TEST RESULTS AND DISCUSSION:

5.1 The index properties of the soil are presented in Table 1 based on various soil tests.

Table 1. Index Properties of Soil

S.No.	Particular	Test Result
1	Soil Classification	CS
2	Liquid Limit (%)	46
3	Plastic Limit	29.17
4	Plasticity Index	17.83
5	Optimum Moisture content (%)	17.6
6	Maximum Dry density (g/cc)	19.4
7	Specific gravity	2.48

5.2 Permeability test

Testing of permeability test of various sample of soil were performed as per IS 2720 part 17 - 1986.

From the Fig. 1 and 2 shows that the permeability value decreases when percentage of PET waste increases. The Size of PET waste also influences the permeability. Size of PET waste increases the permeability value decreases. The major reason behind that plastic is impermeable material, when it is included in soil it reduces pores.

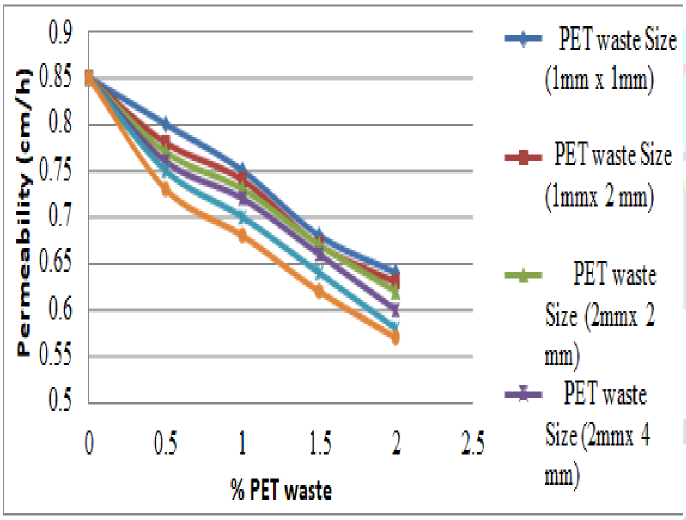

Figure : 1 Variation of Permeability for varied addition of PET waste of Size 1mm,2mm and 4mm

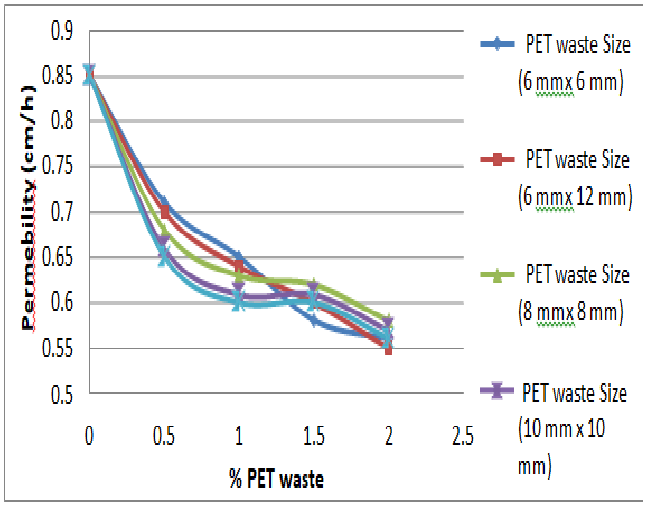

Figure : 2 Variation of Permeability for varied addition of PET waste of Size 6 mm, 8mm, 10mm and 12 mm

5.3 DIRECT SHEAR TEST

Testing of direct shear test of various samples of soil were performed as per **IS 2720 part 13 - 1986**.

The Internal friction angle obtained of poorly graded clay soil is 4^0 and cohesion value 0.231 Kg/cm^2.Fig. 3 and 4 indicates that the internal friction angle and cohesion value mutually increases upto 2 % addition of PET waste of size 1 mm and 2 mm. Fig. 5 and 6 indicates that the upto 6mm x 6mm size, the value of internal friction angle and cohesion is increases mutually, after that the increase the size of PET waste decrease the value of internal friction angle and cohesion takes place. Fig. 7 and 8 indicates that the size of PET waste increases, the cohesion value and internal friction angle were decreases at 1.5 and 2.0 % variation of PET waste.From the above results, it was observed that, 6 mm x 6 mm size plastic waste shows maximum value of internal friction 5.2^0 and cohesion 0.322 kg/cm^2 at 2 % variation. The maximum of 30 % increment of internal friction angle and 39 % cohesion value was achieved.

It is also observed from the test results that, the 12 mm x 12 mm size PET waste show lowest value of internal friction angle and cohesion.

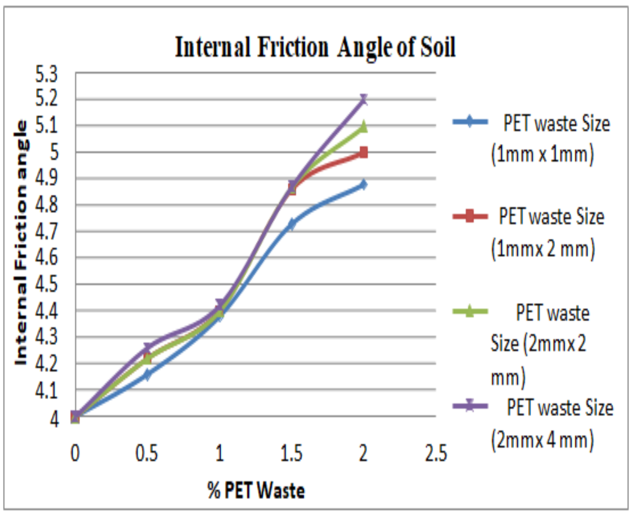

Figure : 3 Variation of Internal Friction angle for varied addition of PET waste of Size 1mm and 2mm

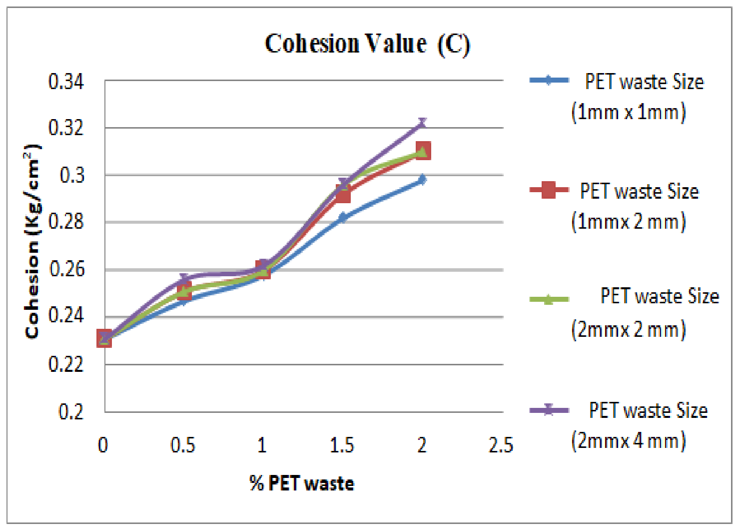

Figure : 4 Variation of Cohesion Value for varied addition of PET waste of Size 1mm and 2 mm

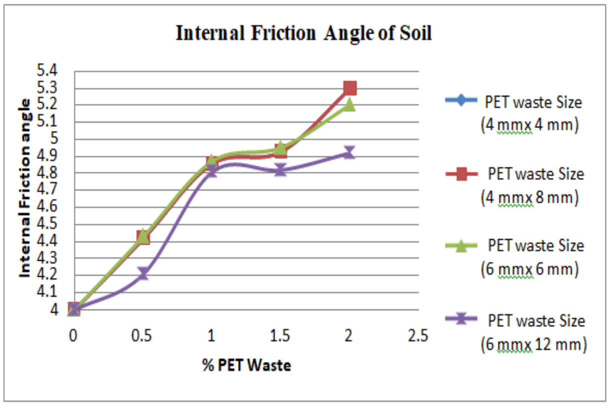

Figure : 5 Variation of Internal Friction angle for varied addition of PET waste of Size 4mm and 6 mm

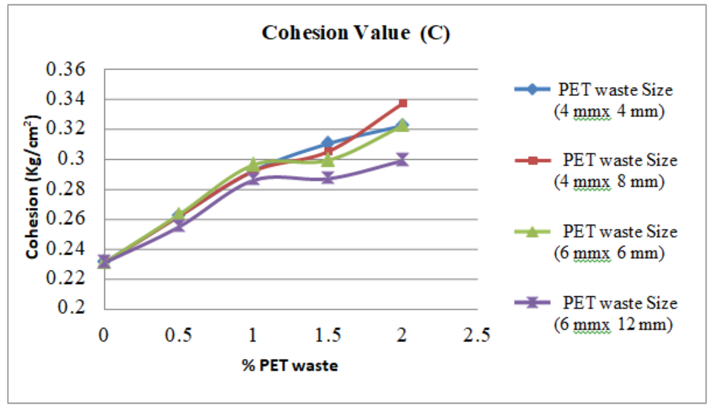

Figure : 6 Variation of Cohesion Value for varied addition of PET waste of Size 4mm and 6 mm

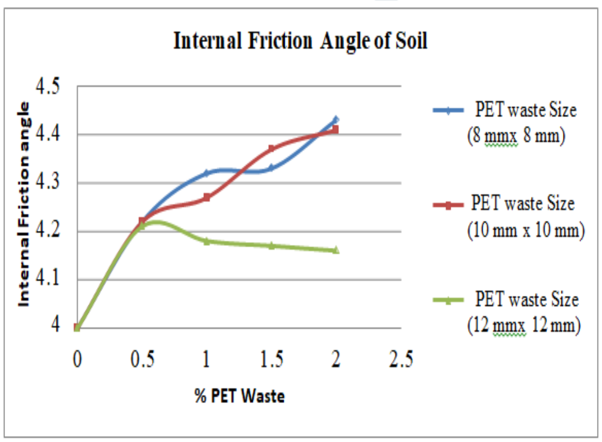

Figure : 7 Variation of Internal Friction angle for varied addition of PET waste of Size 8 mm, 10 mm and 12 mm

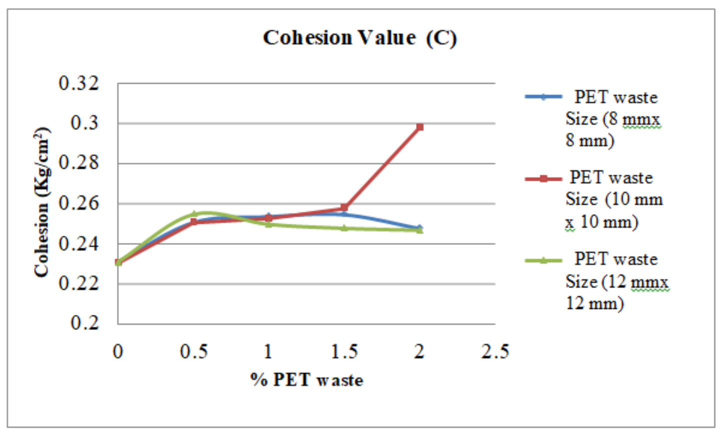

Figure : 8 Variation of Cohesion Value for varied addition of PET waste of Size 8 mm, 10 mm and 12 mm

IV CONCLUSION AND SUMMARY

The repurposing of specific inorganic solid wastes in civil engineering projects is gaining popularity, contributing to the mutual improvement of the environmental sector by reducing residual wastes and introducing new geotechnical materials with enhanced mechanical behavior.

A systematic research study has been undertaken to determine the influence of PET waste on the mechanical properties of soil at various proportions. This work considers two factors: the size of PET waste with aspect ratios of 1 and 2, and the percentage variation of PET waste with soil. The soil obtained from the site exhibits the behavior of poorly graded clay, as discussed in the index properties.

The mechanical properties' results were presented and discussed in the preceding chapter, leading to the following conclusions drawn from the test results:
i. The permeability value of the soil decreases with an increase in the percentage of PET waste content of different sizes in the soil sample.
ii. An increase in the value of the internal friction angle and cohesion is observed with an increase in the inclusion percentage of PET waste. Specifically, a maximum of 30% and 39% for internal friction and cohesion values, respectively, was achieved with the inclusion of PET waste.

Literature cited:

[1]. Al-Taie, A. J., Al-Obaidi, A., & Alzuhairi, M. 2020. Utilization of depolymerized recycled polyethylene terephthalate in improving poorly graded soil. Transportation Infrastructure Geotechnology, 7(2), 206-223.

[2]. Awoyera, P. O., & Adesina, A. 2020. Plastic wastes to construction products Status, limitations and future perspective. Case Studies in Construction Materials, 12.

[3]. Carvalho, B., Casagrande, M., & Farias, M. 2019. Evaluation of resilient behavior of a clayey soil with polyethylene terephthalate (PET) insertion for application in pavements base. In E3S Web of Conferences (Vol. 92, p. 12006). EDP Sciences.

[4]. Dutta, S., Nadaf, M. B., & Mandal, J. N. 2016. An overview on the use of waste plastic bottles and fly ash in civil engineering applications. Procedia Environmental Sciences, 35, 681-691.

[5]. Fauzi, A., Rahman, W. M. N. W. A., & Jauhari, Z. 2013. Utilization waste material as stabilizer on kuantan clayey soil stabilization. Procedia engineering, 53, 42- 47.

[6]. Gayatri, A., & Verma, A. K. 2020. Geotechnical Characterization of Expansive Soil and Utilization of Waste to Control Its Swelling and Shrinkage Behaviour. In Recent Developments in Waste Management (pp. 11-21). Springer.

[7]. Hussain, I & Singhvi, B. 2020. Utilization of Plastic waste in soil Reinforcement: A review. *International Journal of Technical Research & Science.* ISSN No. 2454-202, Vol (**5**), November 2020, 32-37.

[8]. Hussain, I & Pandya P., Assessment of the Unconfined compressive strength value of soil using PET plastic waste : Mathematical modelling, International Journal of Research and analytical review (IJRAR) EISSN 2348-1269, P ISSN 2349-5138.

[9]. Hussain, I & Pandya P., UTILIZING MATHEMATICAL MODELS FOR THE ASSESSMENT OF SOIL CALIFORNIA BEARING RATIO (CBR) ENHANCED BY PET PLASTIC WASTE, International Journal of Emerging Technology and innovative Research (JETIR) EISSN 2349-5162, Vol 10 Issue10..

[10]. Ilieş, N. M., Cîrcu, A. P., Nagy, A. C., Ciubotaru, V. C., & Kisfaludi-Bak, Z. 2017. Comparative study on soil stabilization with polyethylene waste materials and binders. Procedia Engineering, 181, 444-451.

[11]. IS: 1498 -1970. Classification and identification of soil for general engineering purposes, Bureau of Indian standard (BIS),New Delhi, India.

[12]. IS: 2720 (Part 10 & 11) -1993. Determination of the shear strength parameter of a specimen tested in unconsolidated undrained triaxial compression with & without the pore water pressure, Bureau of Indian standard (BIS) , New Delhi, India.

[13]. IS: 2720 (Part 10) -1991. Determination of Unconfined compressive strength, Bureau of Indian standard (BIS) , New Delhi, India.

[14]. IS: 2720 (Part 13) -1991. Direct shear test, Bureau of Indian standard (BIS) , New Delhi, India.

[15]. IS: 2720 (Part 16) -1987.Determination of CBR, Bureau of Indian standard (BIS) , New Delhi, India.

[16]. IS: 2720 (Part 17)-1986.Laboratory determination of permeability, Bureau of Indian standard (BIS) , New Delhi, India.

[17]. IS: 2720 (Part 1) -1983.Preparation of dry soil sample for various test, Bureau of Indian standard (BIS), New Delhi, India.

[18]. Jin, D. C., Kalumba, D., & Chebet, F. C. 2019. Laboratory Investigation of Recycled polyethylene Terephthalate (PET) as Soil Reinforcement Material.

[19]. Kassa, R. B., Workie, T., Abdela, A., Fekade, M., Saleh, M., & Dejene, Y. 2020. Soil Stabilization Using Waste Plastic Materials. Open Journal of Civil Engineering, 10(01), 55.

[20]. Kumar, T., Panda, S., Hameed, S., & Maity, J. 2018. Behaviour of soil by mixing of plastic strips. International Research Journal of Engineering and Technology (IRJET), 5(05)..

[21]. Mahali, K. P., & Sinha, A. K. 2015. Utilization of stone dust with plastic waste for improving the subgrade in highway pavement construction. International Journal Engi ineering Technology, 4(6), 29-35.

[22]. Mallikarjuna, V., & Mani, T. B. 2016. Soil stabilization using plastic waste.International Journal of Research in Engineering and Technology, 5(05).

[23]. Manuel, M., & Joseph, S. A. 2014. Stability analysis of kuttanad clay reinforced with PET bottle strips. International Journal of Engineering Research & Technology (IJERT) ISSN, 2278-0181.

[24]. Mishra, B., & Gupta, M. K. 2018. Use of randomly oriented polyethylene terephthalate (PET) fiber in combination with fly ash in subgrade of flexible pavement. Construction and Building Materials, 190, 95-107.

[25]. Mohammed, M. A., Mohammed, A. R. E., & Elgady, I. Y. 2018, "evaluation of the effect of plastic bottle (pet) waste on stablization of clay". International journal of engineering sciences & research technology..

[26]. Pal, S., Maity, J., & Chattopadhyay, B. C. 2018. Application of waste plastic bottle for the improvement of alluvial soil. International Research journal of engineering & technology (IRJET).2158-2161.

[27]. Peddaiah, S., Burman, A., & Sreedeep, S. 2018. Experimental study on effect of waste plastic bottle strips in soil improvement. Geotechnical and Geological Engineering, 36(5), 2907-2920.

[28]. Rawat, P., & Kumar, A. 2016. Study of CBR behaviour of soil reinforced with HDPE strips. METHODOLOGY, Indian Geotechnical Conference. 2, x10-4.

[29]. Salazar, L. A., Díaz, F. R., & Ramírez, G. D. 2019. Shear strength of a reinforced clayey soil with crushed polyethylene terephthalate. Congreso Internacional de Innovacióny Tendencias en Ingenieria (CONIITI) (pp. 1-6). IEEE.

[30]. Salimi, K., & Ghazavi, M. 2019. Soil reinforcement and slope stabilisation using recycled waste plastic sheets. Geomechanics and Geoengineering, 1-12.

[31]. Singh, K., & Mittal, A. 2019. Soil Stabilisation Using Plastic Waste. In Recycled Waste Materials (pp. 91-96). Springer, Singapore.

[32]. Soltani-Jigheh, H. 2016. Compressibility and shearing behavior of clayey soil reinforced by plastic waste. International Journal of Civil Engineering, 14(7), 479-489.

[33]. Tomar, A., Sharma, T., & Singh, S. 2020. Strength properties and durability of clay soil treated with mixture of nano silica and Polypropylene fiber. Materials Today: Proceedings.

[34]. Yarbasi, N., & Kalkan, E. 2020. The mechanical performance of clayey soils reinforced with waste PET fibers. International Journal of Earth Sciences Knowledge and Applications, 2(1), 19-26.