International Journal For Advanced Research In Science & Technology
A peer reviewed international journal www.ijarst.in
ISSN: 2457-0362

SOIL STABILIZATION BY USING WASTE PLASTIC

[1] P.Manikanta, [2] Nyalapally Manasa,[3] Adla Rojarani, [4] Kolluri Swathi ,[5] Gollavathula Prasanna

[1]Assistant Professor,Department Of Civil Engineering ,Princeton Institute Of Engineering & Technology For Women Hyderabad.

[2,3,4,5]students, Department Of Civil Engineering ,Princeton Institute Of Engineering & Technology For Women Hyderabad.

Abstract-Soil stabilization is one of the best methods for improving index properties, physical properties like shear strength, bearing capacity etc. of the soil. For soil stabilization various admixture such as cement, lime, fly ash, gypsum etc. can be used. But these admixtures are costly so their uses for soil stabilization are limited. In some research it is found that utilization of waste material like plastic, bamboo etc. are quite helpful in stabilization of soil. In present world there is scarcity of good soil which makes construction process difficult. So to enhance the properties of soil so that it can be used for various constructions there is need to add the suitable admixture in soil. These admixtures should enhance properties of soil and also be economical.

The foundation is very important for any structure and it has to be strong enough to support the entire structure. For foundation to be strong the soil around it plays a very important role. A review paper is presented here to focus on soil reinforcement by using shredded waste plastic products. The tests such as liquid limit, plastic limit, standard proctor compaction test, California bearing ratio (CBR) test and unconfined compressive strength (UCS) have been conducted to check the improvement in the properties of problematic soil.

Keywords: soil reinforcement, California bearing ratio, unconfined compressive strength, problematic soil etc.

1. INTRODUCTION

Soils with moral engineering properties are used as fill material for different engineering applications like backfilling material in highway embankment or the road's layers and building foundation. In some cases, suitable soils are not found easily and, therefore, the use of alternate soil types, possessing undesirable engineering properties such as poorly graded soil, alternative due to its susceptibility to water and wind action and its compaction difficulty, sandy soil is not suitable for roadbed construction [1]. Thus, the use of this substitute requires enhancing the geotechnical properties of poorly graded soil. The mechanical parameters such as compaction and shear strength of poorly graded soil can enhance to meet the desirable engineering standards. In general, different type of additive can be used for improving geotechnical properties of soil; Such as silica fume, cement kiln dust, fly ash, cohesive admixture and treated coir fiber [1]

Conservation of the environment and preservation of rapidly diminishing natural resources are the common problems facing the worldwide. Viewing this perspective the world is moving towards sustainable development and these factors are now included in the nation building policies of every country. This study deals with the current issue the state of Rajasthan is facing, which is the safe disposal of plastic waste material.

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. These cities together produced 4059 T/day[24]. Delhi takes first position in generating maximum plastic waste followed by Chennai, Mumbai, Bangalore and Hyderabad. As plastic

is non-decomposable material or has very slow rate of decomposition so it will accumulate in the environment and adversely affects the ecosystem. Plastic which acts as pollutants are divided into two types according to their sizes. These are micro and macro pollutants. As plastic are economical and durable than other materials so their production by humans are quite high. The chemical structures of plastic make them resistant to many natural process of decomposition as a result they are almost non decomposable material.
After this study we will use plastic waste to improve soil properties and utilized in design of Pavement, machine foundation and various civil engg. Construction aspect.

1.1 Soil Reinforcement Techniques

There are many methods of soil reinforcement in use. The degree of enhancement of insitu soil may differ within a certain method and also between other methods. The purpose behind is that the soil exists in a broad range of types and different soil behave differently to stabilizer.
The important accessible methods are

- Mechanical reinforcement
- Cement stabilisation
- Lime stabilisation
- Chemical stabilisation
- Thermal stabilisation
- Bitumen stabilisation

Mechanical reinforcement is termed as granular stabilization. In this techniques, mechanical energy is used (rollers, plate, compactors, tampers etc. By choice or nature of soil) to improve the soil properties by compaction. Mechanical stability depends upon the degree of compaction. Basically, the compaction is done at optimum water content. This techniques, preferably for construction of embankment of roads, railways etc.
Cement stabilization is most commonly used for road construction. In this techniques, successfully to strength the granular soils, silts and medium plastic clays. According to various research literatures, the cement proportion added to soil 5 to 14 percent of soil volume.
Lime stabilization has been in use to stabilize clayey soils. When lime reacts with soil there is exchange of cations in the absorbed water layer and the decrease of plasticity of the soil occurs. The reinforced soil is more friable than the original clay, and suitable for sub-grade.
Chemical stabilization is done by adding different chemicals such as calcium chloride, sodium chloride, sodium silicate, polymers, chrome lignin etc. The main advantage of these techniques is that the setting and curing time can be controlled. By chemical grouting, it is also possible to stabilize fine sands and silts.
By thermal techniques, soil can be reinforced for expediting construction facilities. A reliable temporary expedient to facilitate construction of open and underground excavation is reinforcing the soil by freezing the pore water. When a clayey soil is heated, there is a progressive improvement in strength. This method is uneconomical and poor response in case of insitu soil.
Bitumen has a binding property, when it's mixed with soil its imparted binding behavior and makes soil waterproof. Water proofing property imparted to soil helps in retaining its strength in presence of water. In case of fine grained soil bituminous material fill the voids. So the soil is preventing from direct contact with water. This method is widely used in road construction.

1.2 Types of Plastic Waste

The Society of the Plastics Industry, Inc. (SPI) introduced its resin identification coding system in 1988 at the urging of recyclers around the country. The seven types of plastic include:

- Polyethylene Terephthalate (PETE or PET)
- High-Density Polyethylene (HDPE)
- Polyvinyl Chloride (PVC)
- Low-Density Polyethylene (LDPE)
- Polypropylene (PP)
- Polystyrene or Styrofoam (PS)
- Miscellaneous plastics (includes: polycarbonate, polylactide, acrylic, acrylonitrile butadiene, styrene, fiberglass, and nylon)

Plastics are generally categorized into two types:

Thermoplastics: Thermoplastics or Thermo-softening plastics are the plastics which soften on heating and can be molded into desired shape such as PET, HDPE, LDPE, PP, PVC, PS etc.

Thermosets: Thermoset or thermosetting plastics strengthen on heating, but cannot be remolded or recycled such as Sheet Molding Compounds (SMC), Fiber Reinforced Plastic (FRP), Bakelite etc. are the examples of the same.

1.3 Effects of Plastic Waste on Environment

As plastic is non-decomposable material or has very slow rate of decomposition so it will accumulate in the environment and adversely affects the ecosystem. Plastic which acts as pollutants are divided into two types according to their sizes. These are micro and macro pollutants. As plastic are economical and durable than other materials so their production by humans are quite high. The chemical structures of plastic make them resistant to many natural process of decomposition as a result they are almost non decomposable material. Some harmful effects of plastic waste are noted below.

When plastic bags left in the soil, it slowly releases toxic compounds which ultimately reach the ground water table. If any living being drinks this water it will cause severe health issue.

Clogging of sewage system by plastic bags mostly in urban areas causes severe harms to the environment. This clogging of 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 collects the pollutants from the area and spread them as far as it flow which is an extra problem associated with it.

Plastic waste disposes into the ocean releases toxic chemical which will sometimes leads to extinction of some aquatic species..

It leads to the loss of wildlife. Many animals after eating plastic suffer from severe health problems. Any animal whose has eaten plastic suffers from obstruction in intestines which leads to a quite long and painful death. Some animals died after eating plastic because as plastic decomposes very slowly it makes the animal full which ultimately leads to death due to malnutrition. It also deteriots the natural beauty. It ruins the aesthetic appearance of every ecosystem

1.4 Plastic Waste Management in India

Recycle of waste plastic in India is not properly organized. Around 60% of the waste plastic which is collected and sorted gets recycled and ready for the use of people. A national plastic waste management council task force has been setup by collaboration of government of India, Ministry of Environment with the association of department of petroleum and chemical, Ministry of Union affairs and different groups or association of plastic manufacturers. Their aim is to properly manage the recycling or managing of plastic waste. In India municipal solid waste contain around 4% of plastic waste. It is a major source of hazard to the environment. Polythene bags if burnt irresponsibly for disposal releases high amount of toxic gases like carbon monoxide, chlorine, sulphur di -oxide and nitrogen dioxide.

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal www.ijarst.in
ISSN: 2457-0362

1.5 Regulations and Legislations for Plastic Waste Management in India

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

BIS (Bureau of Indian standards) have issued some guidelines on plastic waste recycle which includes code of practice for collecting the plastic waste, up gradation of technique of sorting the waste plastic etc. 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.

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.

PET manufacturers has formed a national association of PET which will look on organized collection and recycling of PET bottles.

1.6 Objective of the Review Study

- To understand the various solution of disposal of plastic waste with importance in soil stabilization.
- To understand the optimum quantity of use of plastic waste to increase the mechanical and index properties of soil.
- To identify the research gap in this field.

2. REVIEW OF LITERATURE

A various studies are available for utilization of plastic waste for soil stabilization.

Fauzi et al. (2013) investigated the utilization of High Density Polyethylene (HDPE) and Glass as material stabilizer in Kuantan clayey soil stabilization. His research conducts soil engineering properties and strength test for various contents of HDPE and glass to different types of clayey soil from various sites in Kelantan. The Standard Compaction and California Bearing Ratio (CBR) were applied in soil samples to estimate the optimum mixture design. The samples were set up by mixing soil samples with various content of stabilizer at optimum water content. The variation content of stabilizer was 4%, 8% and 12% by dry total weight. The accomplishment of subgrade stabilization depends on the engineering properties of clay and characteristic of stabilizer [5, 6, 7, 8, 9, and 10]. The laboratory test results were shown the engineering properties of Kuantan Clayey soil and CBR were improved by adding Cutting HDPE and Crushed Glass as stabilizer.

Manuel et al. (2014) carried out stability analysis of kuttanad clay reinforced with PET bottle strips. In this study, he was taken Kuttanad clay spread over the Kuttanad region in the state of Kerala, India. These clays are characterized by high compressibility, low shear strength and high percentage of organic matter, which are unfavorable from the geotechnical point of view. For the study plastic strips were obtained from PET water bottle. The strips were cut into pieces of length 25mm having average width 10mm. It is to be noted the that the mould diameter would be at least 4 times the maximum strip length, which ensures the sufficient room for the strip to behave freely and independent of mould confinement. Strips are randomly mixed with soil in varying percentages (0, 0.25, 0.5, 0.6, 0.75, and 1) by dry weight of soil. Plastic reinforced soils were prepared manually by hand mixing. Oven dried soil after passing through 4.75 mm sieve was taken and water added and mixed uniformly. For a particular percentage of fiber content, the 1/3 rd of total amount of plastic strips were distributed evenly and mixed thoroughly with wet soil. After mixing the 1/3rd amount, another 1/3rd amount were mixed in the same way. Lastly the rest 1/3rd amount was mixed

with the wet soil. The wet plastic-mixed soils were then used for various tests. Standard Proctor test, CBR test, unconfined compression test and Triaxial compression test were done in the laboratory. He was concluded that Analysis of foundation using PLAXIS software show that the total displacement of foundation decreases from 0.2984m (before stabilization) to 0.0935m after stabilizing soil upto 1m depth at a load of 45kN/m^2. The maximum dry density increase with the increase in the strip content upto optimum strip content and then decreases. CBR value increases with the increase in the strip content upto optimum strip content and then decreases. The optimum strip content corresponding to maximum improvement in CBR value is found to be 0.6%. The unconfined compressive strength of the sample increase from 5 kN/m^2 (pure clay) to 24.69 kN/m^2,cohesion of the sample increase from 5 kN/m^2 (pure clay) to 17.5 kN
/m^2 and the angle of internal friction (Ø) of the sample increase from 30 (pure clay) to 190.

Mahali et al. (2015) conducted a research work to study Utilization of stone dust reinforced with PET strips (Polyethylene terephthalate) improving the subgrade soil. In this study investigate the effect of stone dust reinforced with PET strips by conducting a series of CBR tests. Three different sizes of PET Strips as length of 10mm, 20mm, and 30mm of width 10mm were used. The plastic strips were mixed as 0.25% to 2% with dry weight of stone dust. He was concluded that Maximum dry density of fiber mix stone dust increases with increase in fiber content. Optimum moisture content decreases with addition of plastic fibers. Mixing of fiber can increase the strength of stone dust. The addition of PET strips, a waste material, to stone dust increases the CBR value. The reinforcement benefit increases with an increase in waste plastic strip content and length. The maximum CBR value of reinforced system is approximately 2.79 times that of unreinforced system. This study is recommended to cost economics of the use of waste materials in base course in rural roads. Reinforced stone dust is more effective, it can be used as filling material in embankment construction over saturated clay.

Mallikarjuna et al. (2016) carried out research work on stabilization of Black cotton soil using plastic waste. In this study, he focused to overcome the problems experienced in Amaravathi, the capital of newly formed Andhra Pradesh State. He was carried out experimental program for stabilization of Black Cotton Soils in the Capital Region i.e., Amaravathi of newly formed Andhra Pradesh, with the utilization of Plastic waste as soil stabilizer. Different contents of plastic strips (% by weight varying from 0% to 8%) are added to the Black Cotton Soil and the optimum percentage of plastic strips in soil was found out by conducting California Bearing Ratio Test. In this study plastic was collected from used plastic chairs are collected and are made into different strips. Plastic strips with a density about 0.42 gm/cc are added to the Black Cotton Soil in percentages of 2, 4, 6 and 8 and the modified proctor test and CBR test has been conducted on the sample. He was concluded that CBR value increase upto 4 % plastic content.

Pal et al. (2018) carried out experimental study, this work involves the stabilization of near surface alluvial clayey soils using randomly distributed waste plastic bottle at varying lengths and percentages by weight of soil. In this work, waste plastic bottles are cut into three different size of 1cm x1cm, 1cm x 2cm, & 1cm x 3cm, and mixed in different proportion of 0.25, 0.5, & 0.75 % by weight of dry soils and different compaction and strength properties have been evaluated. From the study, he has been observed that with the increase in percentage of waste plastic bottle chips in cohesive soil, maximum dry density decreases whereas optimum moisture content increases.

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, analyze 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 %. He was used 2 mm size PET flakes strip throughout his research. He was 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. He was found 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. His 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 he suggest 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.

Tomar et al. (2020) the main motive of this research is to investigate the optimal combination of Nano-Silica and Polypropylene fiber with clay soil. The engineering properties such as liquid limit, plastic limit, maximum dry density and unconfined compressive Strength (UCS) are analyzed with virgin soil, the soil with Nano-Silica and combination of soil with Nano-Silica and polypropylene fiber. The durability test is performed to understand the durability of stabilized soil by analyzing wetting–drying Cycles Also, Scanning Electron Microscopy (SEM) test is carried out and images are obtained to understand micro-structural modification towards mixture of Nano-SiO2 and PPF. Four different combinations of Nano-Silica at different percentages 1%, 3%, 5% and 7% are used in integration with polypropylene fiber is used in different percentages such as, 0.1%, 0.4%, 0.7%, 1%, and 1.3%. From these experiments, it has been analyzed that with the increase of PPF content in addition to Nano-Silica, the UCS increases and Maximum value of UCS is obtained at 7% of Nano- Silica with 0.7% of PPF. The intermixing of PP fiber with the soil acts as a reinforcing material in binding the soil particles and the ‘bridge effect’ of fiber reinforcement in soil impedes the further development of tension cracks.

3. IDENTIFICATION OF GAP AREA

It is evident from the work reported that though a number of studies available on the utilization of plastic waste on the stabilization of soil. Limited study is available in the literature shows systematic use of plastic waste material in soil stabilization. The available studies are used only for specific soil purpose available at that region. There is lot of research gap in this field due to limitation of this work.

CONCLUSION

From the studies conducted by various researchers, it can be concluded.

- The plastic waste can improve the strength thus increasing the soil bearing capacity of the soil.
- Every year a lot of plastic waste is generated and occupied a lot of space. It is necessary to find an alternate solution for this problem. Based on literature, one of the solutions is use of shredded plastic waste in soil reinforcement and stabilization.

- Results of various researchers give positive indication to the possibility of using the versatile plastic products such as polyethylene terephthalate (PET), plastic bags, bottles, containers and packaging tapes etc. for reinforcement of soil.
- Disposal of plastic waste without environmental hazards has become a real challenge for our society. Therefore, the use of plastic waste as soil reinforcement is a cost effective and profitable use.
- Use of plastic waste as reinforcement is recommended to reduce the quantities of plastic waste, which creates the disposal problem. Successful application of plastic waste could help to reduce the quantity of plastic waste which is disposed of to landfills and contribute to sustainable development by providing low cost material to the resource intensive geotechnical industry
- Nominal research has been done in India to determine the availability of feasible waste materials and the suitability of these materials for Indian roads. The results are better and more durable with a higher strength and reduction of permeability of the soil. However further study is needed:
  - To optimize the percentage of plastic waste content.
  - Large scale test is also needed to determine the boundary effects influence on the test results.

REFRENCES

[1] Al-Taie, A. J., Al-Obaidi, A., & Alzuhairi, M.. Utilization of depolymerized recycled polyethylene terephthalate in improving poorly graded soil. Transportation Infrastructure Geotechnology, 7(2), 206-223. 2020.
[2] Awoyera, P. O., & Adesina, A. Plastic wastes to construction products Status, limitations and future perspective. Case Studies in Construction Materials, 12, e00330. n.d. (2020)
[3] Bureau of Indian standard (BIS). Classification and identification of soil for general engineering purposes, IS 1498 (1970), New Delhi, India. n.d.
[4] Bureau of Indian standard (BIS). Determination of the shear strength parameter of a specimen tested in unconsolidated undrained triaxial compression with & without the pore water pressure, IS 2720-10 & 11 (1993), New Delhi, India. n.d.
[5] Bureau of Indian standard (BIS). Determination of Unconfined compressive strength, IS 2720-10 (1991), New Delhi, India. n.d.
[6] Bureau of Indian standard (BIS). Direct shear test, IS 2720-13 (1991), New Delhi, India. n.d.
[7] Bureau of Indian standard (BIS).Determination of CBR, IS 2720-16 (1987), New Delhi, India. n.d.
[8] Bureau of Indian standard (BIS).Laboratory determination of permeability, IS 2720-17 (1986), New Delhi, India. n.d.
[9] Bureau of Indian standard (BIS).Preparation of dry soil sample for various test, IS 2720-1 (1983), New Delhi, India. n.d.
[10] Carvalho, B., Casagrande, M., & Farias, M. 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. n.d. 2019.
[11] Dutta, S., Nadaf, M. B., & Mandal, J. N. An overview on the use of waste plastic bottles and fly ash in civil engineering applications. Procedia Environmental Sciences, 35, 681-691. n.d. 2016
[12] Fauzi, A., Rahman, W. M. N. W. A., & Jauhari, Z.. Utilization waste material as stabilizer on kuantan clayey soil stabilization. Procedia engineering, 53, 42-47. n.d. 2013
[13] Gayatri, A., & Verma, A. K.. 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. n.d. 2020

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

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

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

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

[18] Mahali, K. P., & Sinha, A. K. . Utilization of stone dust with plastic waste for improving the subgrade in highway pavement construction. Int J Res Eng Technol, 4(6), 29-35. n.d. 2015

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

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

[21] Mishra, B., & Gupta, M. K. . 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. n.d. 2018.

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

[23] Pal, S., Maity, J., & Chattopadhyay, B. C.. Application of waste plastic bottle for the improvement of alluvial soil. n.d. 2018.

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

[25] Rawat, P., & Kumar, A. Study of CBR behaviour of soil reinforced with HDPE strips. METHODOLOGY, 2, x10-4. n.d. 2016.

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

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

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

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

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

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