Soil Stabilization Using Waste Plastic Bottles Fibers: A Review Paper

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Abstract. Nowadays plastic has a major role in our life use, but the increased usage of it led to a serious challenge which is plastic waste. Plastic waste is increasing day by day and which led to many bad disposal methods like burning and due to that there are many environmental and pollution problems. Therefore, there is a need to seek for safe and effective disposal methods to protect our plant and next generations’ future. One of the effective and safe solutions is using plastic waste in civil engineering construction as this solution is eco-friendly where it will provide a safe disposal as well as in engineering there is always a seek for economical materials and as plastic waste is almost for free. In addition, adding these materials may improve the properties of the construction materials. This article reviews all the published trials of using waste plastic bottles fibers as soil improvement material to examine the effectiveness of using this material as a reinforcing material in improving soil properties. As well as to provide a data base of information regarding the best dimensions and percentages. After reviewing the literature, it was found that waste plastic bottles can effectively be used as a reinforcing material and it is an eco-friendly solution. But the best benefit is it really economical as this solution has showed good improvement in soil properties this can reduce the thickness of the pavement in highways construction as well as it provided a good stabilization method rather than the other expensive methods. This material also can solve the problem of time as the other stabilization take much time which delay the construction process. Also, it was found that the addition of (0-5) % with higher aspect ratios give the optimum results.

1. Introduction
In construction world, it is important for structures to be strong enough and to have a long-lasting time without any problems or cracks. In order for the structures to be strong enough, the soil supporting it plays a very critical role. Where, soil is the base material that supports the structure. So, working with soils, needs to have a good knowledge about soils properties and factors affecting their behavior, [1].

In construction process, it is much frequent that many weak soils like expansive soils face the construction process. Where, the foundation of any infrastructure is essential in transferring the load safely from superstructure to the underlying soil without compromising serviceability. However, many times, foundations are to be built on weak soils, causing excessive settlements due to lower bearing capacity. This can lead to damages, durability reduction, and performance level deterioration, [2].

There many solutions for such problems and which are stabilization methods. Where soil stabilization is defined as the process of improving the properties of weak soil to make it stronger and have more
stability. So, in other words, soil improvement or stabilization is the process that assists to get and archive the required properties in a soil needed for a construction work. Stabilization will increase the engineering properties of a soil and/or management the shrink-swell properties of a soil, therefore up the load bearing capability of soil to support structures and pavements, [3].

From the beginning of the construction work, it is necessary to enhance the soil properties. Ancient civilizations of the Chinese, Romans and Incas used several methods to enhance soil strength etc., some methods were really effective that their buildings and roads still exist, [4].

Nowadays there are many ways of soil stabilization like Mechanical Stabilization, Chemical Stabilization, Polymer and Plastic Stabilization and etc., each of these has its advantages and disadvantages but the main problem is that these methods do not protect the environment, [5].

Where, it is well established that there are environmental problems facing planet earth, where there is waste disposal problem. These problems are initiating from the wastes and one of the biggest produced waste is the plastic ones, where plastics comprise 12.3% of total waste produced most of which is from discarded PET water bottles, [6]. Americans alone, throw away 35 billion plastic bottles every year, [7]. Also, about 32.5 million tons of plastic waste is generated annually in the United States, which is around 12.8% of entire municipal solid waste, [8]. International Bottled Water Association, proved that plastic bottles consumption increased by 500% over last ten years and more than 1.5 million tons of plastic are used for bottling water every year [9]. Where, every year tons of garbage being burned causing climate change and pollution problems as the amount of plastics of all kinds produced annually in the world has phenomenally increased. Where, plastics are materials widely used that play a significant role in nearly every part of our lives. The largest amount of plastics is used in products and packages (e.g. cans, boxes, cups). Diversity in plastics uses is due to their unique characteristics, low density, fast handling, good mechanical properties, good chemical resistance, excellent thermal and electrical insulating properties and low cost (as compared with other materials). Also, several waste plastic materials are produced by the manufacturing processes, service industries, and municipal solid waste. The growing consciousness of the environment has contributed tremendously to the issues related to the disposal of the wastes produced. The disposal of solid wastes is considered to be one of the world's biggest environmental issues. Since of insufficient garbage capacity and rising plastics prices, waste plastics use has become a desirable option for disposal. 9.2% of plastic waste contains Poly-Ethylene Terephthalate (PET), [10]. Around 5,971 million pounds of PET bottles were shipped into the US economy in 2015, [11]. Because of its lightweight and ease of handling and transport, PET bottles have taken the place of glass bottles as water storage containers [12]. 4.7 and 3.0 million tons of plastic used and discarded in the UK, respectively, in the year 2001. [13]. Only 7% of total post-consumer plastic waste is recycled whilst the remaining 80% is sent to be landfilled and 8% to be incinerated, [13].

So that, broad plastics waste generation requires proper end-of-life management.

The idea of a good solution for these two problems which are soil improvement and waste management is fiber reinforced soil (FRS). Soil Reinforcement is the technique wherein soil is reinforced by means of materials like fibers, strips, geo grids etc. to improve soil properties as shear strength, carrying capacity etc. But, the fibers to be made of waste plastic bottles. Where the reason behind choosing this waste material is that, it is an economical material, as in engineering world there is always a trial to produce more economical materials. Also, this solution is eco-friendly material, way of waste disposal. So that, the advantages of this solution are that it is economical and eco-friendly.

This paper outlies several works that have been carried out on this issue and their attempts to use the waste bottles as reinforcement material to know the effectiveness of using it in such applications as well as to get an idea from the literature and to summarize their findings to get an idea of the best dimensions and percentages these materials can be added. So that, the paper can be used as a data base sources summarizes the whole issue to decide what to do.

2. Literature Review

(Mai et al., 2017), through their study laboratory investigation which was carried out on a sub grade clayey soil sample admixed with plastic bottle strips at different percentages of 1% and 2% with
dimensions of (10*1) mm and they tested them by various experiments like specific gravity, sieve analysis, proctor compaction test, swell index test, unconfined compressive strength test and CBR test. They found that direct shear of soil containing 1% of fibers increased by 66% but in the case of 2% it increased by 115%, unconfined Compressive Strength of soil containing 1% of fibers increased by 70.8% but in the case of 2% it increased by 175%, the specific gravity dry density and optimum moisture content (OMC) increases as the plastic fibers percentage increases, and the Free swell index also increases with fibers. So that, they found that on adding plastic strips into the soil, there has been a positive impact on properties of soil in favor of road construction, [14].

(Singh and Sonthwal, 2016), they collected clayey soil sample with Inorganic clay of low plasticity (CL) and added waste plastic bottles fibers to clayey soil in different sizes (25*5) mm, (35*10) mm, and (50*15) mm by weight of the dry soil sample with percentages (2%, 4% and 6%) of waste plastic bottles material by weight of the dry soil sample, to improve its engineering properties. They found that, the optimum moisture content (OMC) increased and Maximum Dry Density (MDD) decreased in addition of waste plastic bottles strips. The CBR is found to increase with the increase in the percentage of plastic bottles strips content. Where, 6% plastic fibers by weight of dimensions of (25*5) mm is the specific value, where the CBR got improvement of 27.33 % compared to plain soil. They found that, this can noticeably reduce the total thickness of the pavement and hence the total cost. So that, from this study it is clear that the higher percentage was better and the best dimensions were (25*5) mm. and they highly recommended 6 % with size of (25*5) mm, [15].

(Gowtham and Sumathi, 2017), they added PET fibers to expansive soil (Black cotton soil) (clay of high plasticity) with fiber content of (0.5%, 1.0%, 1.5%, and 2.0%) with size passes through (10mm) sieve is used in this investigation by weight of dry soil and tested them for Atterberg’s limit, Compaction Test, Swell Index, CBR, and UCS Test. The result showed fairly significant decrease in the values of Atterberg’s limits liquid limit, plastic limit and plasticity Index. Regarding compaction, with the increase of fibers content optimum moisture content goes on decreasing while maximum dry density goes on increasing, hence compactability of soil increases and making the soil denser and harder. California bearing ratio (CBR) of soil samples increased and also increased as fiber content increased. And in unconfined compressive strength (UCS) compressive strength increased and also increased as fiber content increased. So that, they higher the plastic percentage the higher the improvement in the properties of soil, [16].

(Mohammed et al., 2018), investigated the efficiency of adding of plastic bottle (PET) to clay soil as soil reinforcement. Laboratory compaction and triaxial tests were conducted. Plastic bottles fibers (PET) of length (5-10) mm were used as reinforcement. Soil samples were compacted at maximum dry density with various percentage of waste plastic bottle fibers (0.5, 1.5, 3, 6 and 12 and 15) % of weight of soil. They found that the maximum dry density decreased with the increase in the PET content. Also, an increasing of PET bottle waste content decreased the optimum moisture content. In addition, an increases of PET waste significantly reduced the cohesion(c) of soils. The study generally recommended to use this method but not more than 1.5% of PET bottle waste, [17].

(Consoli et. al., 2002), they put waste plastic fibers to uniform fine sand and tested it under compression tests, tensile tests, and drained triaxial compression tests. They added fibers with percentages of up to 0.9% and with fiber length (up to 36 mm). The results showed that the PET fibers improved the peak and ultimate strength of both soils. Also, the initial stiffness was not that changed by the fiber’s inclusion, [18].

(Babu and Chouksey, 2011), added waste plastic bottles to red soil and sand as reinforcement and a number of triaxial compression (UCC & CU) and one-dimensional compression tests have been performed with various percentages of plastic waste (0.5, 0.75, and 1.0) %. They found that, soil strength enhanced and compressibility reduced noticeably with adding of plastic waste fibers to soil, [9]. (Memon et al., 2019), added PET strips as reinforcement in the fine sandy soil (Passing No. 40). The strips of (35*8) mm were mixed in the soil with 0.5%, 1.0%, 1.5% and 2.0% by dry weight of the soil to investigate soil bearing strength. They found that the maximum dry density of the soil is decreasing with smaller value by the increasing the PET strip content in the soil. As well as, there is an increase in the
CBR value with an increase in the PET strip reinforcement up to 1.5% and then there is decrease in the CBR value.

Generally, they found that the reinforcement of the clayey soil with PET strips is a useful technique to improve the soaked bearing capacity of the soil, and in their research has been found that the CBR has been enhanced by two times of that plain soil by addition of 1.5% of the waste plastic strips. So that, the best recommended parentage is 1.5%, [19].

(Patil et al., in 2016), conducted “Tri-Axial Test & Direct Shear Test” on soil (Black cotton soil) reinforced with Plastic Bottles Strips of size (10*10) mm with percentage of 1%. The results showed that, after adding plastic in soil, cohesion of soil increased by 67.18% by Triaxial test. Similarly, Direct Shear test was performed on the same soil where it was found that the cohesion increased by 24%. The bearing capacity of soil increases and settlement as well as compressibility decreases, [20].

(Gangadhara et. Al, 2017), they added waste plastic bottle strips to red earth to as a reinforcing element to improve the strength characteristic. The red earth is classified as silt soil of low value of compressibility. The added percentages were (0, 1, 2, 3) %. It showed improvement in soil properties, [21].

(Alshkane, 2017), he reinforced sandy soil (passing sieve No. 4) with waste plastic bottles, in three different percentages of (1%, 2%, and 4.0) % by dry weight of sand with lengths of 16 mm and 8 mm. He found that inclusion of plastic fibers increased both angle of internal friction and cohesion. The short fibers gave less ductility than long fibers with the same amount of plastic-fibers but gave similar results of peak stresses. So that, the increase in cohesive property of soil so bearing capacity of soil increases and settlement as well as compressibility decreases. The best percentage was 1%, [22].

(Pal et al, 2018), studied the stabilization of clayey Alluvial 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 (1*1) cm, (2*1) cm, & (3*1) cm, 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.

They found that, maximum dry density of plastic strips mix soil increases with increase of percent of plastic strips up to a certain percentage. Optimum Moisture Content decreases with increase in plastic strips content in soil. The value CBR increases with increase of waste plastic fibers content and it is maximum at dimensions of (1*1) cm, [23].

(Khan and Pachghare, 2015), added fibers to subgrade soil with percentages of (1%, 2%, 3%, 4%, 5% and 6%) and of dimensions of (12*12) mm, (24*12) mm and (36*12) mm. They found that the angle of internal friction increases considerably with inclusion of different percentages of waste plastic fiber. The maximum shear stress also increases up to 5% and then it is decreased. CBR value is increased when percentage content of waste plastic fiber is added. The waste plastic fiber decreases the maximum dry unit weight of soil-subgrade and optimum moisture content (OMC). The best dimensions are (36*12) mm, [24].

(Laskar and Pal, 2013), they reinforced soil with waste bottles plastic to investigate the effect of waste plastic fiber on compaction and consolidation behaviors of reinforced soil. The used soil was local sandy-silt soil with clay. They added fibers with dimensions of (10*5) mm, 4 (10*2.5) mm and 8 (10*1.25) mm in four different percentages 0.00, 0.25, 0.50 and 1.00% by dry weight of the soil. The results of compaction tests indicate that maximum dry density (MDD) of plastic reinforced soil decreases with increasing fiber content. The optimum moisture content (OMC) 17.10%, (for soil alone and soil mixed with waste plastic fibers) which is independent of the amount of fibers. Compression index and coefficient of volume change values decreased as the waste fibers in soil increase up to 0.50%, but numbers increase with further increase of plastic fibers up to 1.00% in soil. The plastic fibers used as soil reinforcement encouraging for potential utilizing in to improve the strength and reduce the settlement, [25].

(Paramkusam, 2013), in this study plastic waste fibers were added to red mud. Dry density and CBR were carried out. The size used of waste plastic fibers was less than 20 mm and bigger than 4.75 mm was taken and added in various percentages of 0.5, 1, 2, 3, and 4% by dry weight of red mud. The study
showed that addition of waste plastic (PET) content in red mud, led to an increase in the dry density and CBR values. Adding fibers of percentage more than 2% does not enhance the dry density and CBR values, [26].

(Jin et al, 2019), reinforced flat sand with waste plastic fibers and applied a numbers of direct shear tests to examine the effectiveness of plastic waste chips in improving the engineering properties. (PET) fibers of sizes of 2 mm, 4.75 mm and 5.6 mm were included in the soils with percentages of (2.5-20) % of dry mass of the soil and mixed randomly to form sand-plastic composite specimen tested in the direct shear test. The results showed serious improvement in the shear strength, cohesion and friction angle of the sands by adding of PET fibers. The highest enhancement in friction angle was gotten at plastic fibers of 10% and 12.5% for the 5.6 mm plastic fibers, [27].

(Mahali and Sinha, 2015), they improved subgrade soil by stone dust reinforced with plastic water bottles PET strips. Where, PET strips obtained from waste plastic water bottle, were mixed randomly with stone dust. A number of CBR tests were conducted. The influence of fibers percentage (0.25-2) % on the CBR of reinforced stone dust was investigated. It was found that addition of PET strips with in stone dust with appropriate amount improved the strength of sub grade. An increase in fibers percentage led to increase in maximum dry density. While on that increase of fibers optimum moisture content decreased. The best enhancement in CBR value of reinforced soil is 2.79 times of plain soil. They study recommended this reinforcing material can used as sub grade material in constructing the rural road over saturated clay, [28].

(Phonsa and Singh, 2019), they utilized waste materials like stone dust and plastic bottle fiber as a strip in the stabilization of clayey soil in the sub grade and to show the influence of stone dust and waste plastic fiber on properties of soil. The plastic was taken 0.4%, 0.8%, 1.2%, 1.6%, 2.0% and stone dust 2%, 4%, 6%, 7%, 8%, 10%, 12%, 16%, 20%. These percentage added to soil sample as to explore the influences of adding them on the optimum moisture content, maximum dry density, and CBR of soil. The maximum dry density of soil is increasing with adding together of stone dust and plastic strips with soil and the optimum moisture content is decreasing with addition of stone dust and plastic strips. The adding of stone dust and PET strips, as a waste material, are increases the CBR value, [29].

(Solanki and Bhattarai, 2019), their study focused on evaluating the properties of a composite developed by stabilizing soil with molten post-consumer polyethylene terephthalate (PET) plastic waste bottles. A total of five soil-plastic composite mixtures mixes were designed using different PET content (20, 25, 30, 45, 50) %. Where, Compressive Strength, Moisture Susceptibility, and D Swell Test were conducted. The developed waste plastic soil reinforced samples showed higher compressive strength values as compared to plain samples. 25% PET content provided maximum strength value among all mixtures tested in this study made soil-plastic composite specimens more moisture and swell resistant. PET content of 25% and above was found to decrease 3-D swell. Both moisture content and density results showed that 25% PET containing soil-plastic composite provides a structure which is densest and strongest among all the mixtures tested in this study, [30].

(Manickam, et. al. 2019), in their study they reinforced red and clay soils with plastic bottles fibers. Where, they added fibers at different contents of waste plastic fibers 0.25%, 0.50%, 0.75%, 1.00% and 1.25% with a length of 10 mm and the quarry dust like 10%,20%,30%, 40% and 50% in order to improve the properties of soil. The found that the quarry dust and waste plastic fiber can be used as an effective stabilizing agent in stabilization of clayey and red soil for using it in a pavement construction. From the experimental results of geotechnical properties of both clay and red soil sample, the strength is gradually increased by adding the admixture such as quarry dust and waste plastic fiber. The quarry dust and waste plastic fiber improved the compressive strength and the addition of the waste plastic fibers played a serious role in the increasing strength of improved soil, [31].
Table 1. Properties of Soil Reinforced with Different Waste Plastic Bottles Fibers Percentages

| Fibers (%) | Direct Shear | CBR % | Compaction OMC % | Compaction MDD % | UCS % | Settlement % | Reference |
|------------|--------------|-------|------------------|------------------|-------|--------------|-----------|
| 0.1        | -            | -     | -                | +12.4            | -     |              | [18]      |
| 0.25       | -            | + (20-35) | (-4.7)-(+16) | (-1.2)-(+0.6) | -     | -            | [23] [31] |
| 0.4        | + (9.1-44.4) | + (6.7-130) | (-8.3)-(+25) | (-2.7)-(+1.5) | (+13-40) | -60          | [16], [17], [18], [9], [19], [35], [33], [31], [29] |
| 0.8        | +4.8         | -     | +6.1            | +2.9             | -     | -            | [29]      |
| 0.75       | +43.9        | + (6.9-170) | (-8.8-16.6) | -0.6             | -     | -            | [9], [23], [35], [31] |
| 1          | + (13-144) | + (53-150) | (-17)-(+50) | (-9.2)-(+17) | (+18-175) | -20          | [14], [16], [17], [9], [19], [20], [21], [22], [24], [35], [34], [33], [31], [31] |
| 1.25       | -            | -     | -33.3           | -32              | +30.7 | -            | [31]      |
| 1.5        | + (76-189) | +120  | (-29)-(+5)      | (-1.7)-(+1)     | (+23-66) | -77          | [16], [17], [19], [35], [33] |
| 2          | + (9.4-167) | + (1.5-36) | (-46)-(+20) | (-17)-(+3.3) | (+6.1-28) | -30          | [15], [16], [19], [21], [22], [24], [35], [32], [17], [21], [24] |
| 3          | +21.7       | -     | (-6.5)-(+50)    | (-25-11)        | -     | -50          | [24]      |
| 4          | + (27.3-32) | + (1.3-16.6) | (-27-8) | (+28-4)        | +18.1 | -            | [15], [22], [24], [32] |
| 5          | 56.9        | -     | -10.5           | -31              | -     | -            | (24)      |
| 6          | +52.5       | + (1-37.5) | (-36)-(+72)    | (-35)-(+4.7)    | +20.3 | -            | [15], [17], [24], [32] |
| 8          | -           | +18.8 | -36.4           | +1.3            | +8.8  | -            | [32]      |
| 9          | -           | -     | +66.6           | -16.6           | -     | -            | [17]      |
| 12         | -           | +77.7 | -19             | -               | -     | -            | [17]      |
| 15         | -           | -     | +94.4           | -23.8           | -     | -            | [17]      |

(+) means Increase, (-) means Decrease

(Hotti, et. al, 2019), in their study the effect of granules made of waste plastic bottles on the index properties of black cotton soil stabilized with 2%, 4%, 6% & 8% granules by weight of the soil. In this study the Atterberg’s limits, differential free swelling, compaction characteristics tests, were conducted. They found that the black cotton soil is a weak soil and therefore improvement of soil is done by using...
plastic granules as a stabilizer to control its stability, swelling and to increase its safe bearing capacity. Where, all of the applied tested showed improvement soil properties, [32].

(Karmacharya and Acharya, 2017), their research involves a study on the possible use of waste plastic bottles as soil reinforcement elements. A series of tri-axial test were carried out on three different samples of soil. Different percentages of waste plastic fibers were used (0.5% to 1.5%) by weight of dry soil. They found that 25%-125% enhancement in shear strength of soil by the adding of 0.5% -1.5% of waste plastic waste fibers by weight of soil, [33].

(Gangadhara, et. al, 2016), They added shredded plastic strips to poorly graded sand, As the plastic content increases the shear strength parameters such as cohesion and angle of internal friction increases. And an increase in the plastic fibers improved the shear stress-strain behavior where it got a maximum peak stress at considerably lower strains. As plastic (%) content increases in sand bed the load carrying capacity of the footing increases up to certain extent beyond that it decreases, [34].

(Vinoth, et. al, 2018), in this study they added waste plastic bottles fibers to soil with percentages of 0.25%, 0.50%, 0.75% and 1% with dimensions of (20*3*0.5) mm. where, they found that addition of fibers can increase the CBR of soil and also increases the stability of soil, [35].

In Table 1 the summary of the literature review and properties of soil stabilized with various waste plastic bottles fibers percentages is shown.

3. Conclusions

After reviewing the literature, the following conclusion can be drawn:
- Adding PET Fibers is an economical and eco-friendly solution.
- Fiber Reinforced Soil (FRS), improves soil strength and its engineering behaviors.
- Properties of soil can be improved by using waste plastic as stabilizer: - CBR value, Increase shear strength, Reduction in consolidation settlement, Reduction in swelling, Reduction in cracks.
- The best fibers percentage is between (0-5) %.
- Regarding the dimensions it clear that a higher aspect ratio gives better results.

References

[1] Gupta HK, Gupta AK, Awasthi S 2017 International Journal of Engineering Technology Science and Research 4(8) 456- 460.
[2] Gowtham S, Naveenkumar A, Ranjithkumar R, Vijayakumar P, Sivaraja M 2018 International Journal of Engineering and Techniques 4(2) 146-150.
[3] Tejeswini K 2013 Engineering behavior of soil reinforced with plastic strips Research and Development 3(2) 83-88.
[4] Zuber SZS, Kamarudin H, Abdullah MMAB, Binhussain M 2013 Australian Journal of Basic and Applied Sciences 7(5) 258-265.
[5] Afrin H 2017 International Journal of Transportation Engineering and Technology 3(2) 19-24.
[6] Ramadevi K, Manju R 2012 International journal of emerging technology and advanced engineering 2(6) 42-46.
[7] Plastics Europe 2014 Plastics The Facts 2014/2015 An Analysis of European Latest Plastics Production Demand and Waste Data.
[8] Environmental Protection Agency (EPA) 2015 Advancing Sustainable Materials Management: 2013 Fact Sheet, Assessing Trends in Material Generation Recycling and Disposal in the United States June 2015.
[9] Babu GS, Chouksey SK 2011 Waste management 31(3) 481-488.
[10] Arun C, Ranajit B, Hall AJ 2000 Technical and institutional options for sorghum grain mold management, Proceedings of an international consultation ICRISAT Patancheru, India.
[11] National Association for PET Container Resources Member (NAPCOR) 2016 Postconsumer PET Container Recycling Activity in 2015 Report Florence KY.
[12] Frigione M 2010 Waste Management 3 1101-1106.
[13] Siddique R, Khatib J, Kaur I 2008 Waste Management 28 1835-1852.
[14] Mai R, Sarathkumar V, Sathish DN 2017 *International Journal of ChemTech Research* **10**(11) 127-130.

[15] Singh J, Sonthwal V, Rattan J 2017 *International Journal on Emerging Technologies* **8**(1) 01-04.

[16] Gowthami S, Sumathi R 2017 *International Journal of Latest Research in Engineering and Technology* **3**(7) 24-30.

[17] Mohammed MA, Mohammed ARE, Elgady IY 2018 Evaluation of The Effect of Plastic Bottle (Pet) Waste on Stabilization of Clay, *International Journal of Engineering Sciences & Research Technology*.

[18] Consoli NC, Montardo JP, Prietto PDM, Pasa GS 2002 *Journal of Geotechnical and Geoenvironmental Engineering* **128**(6) 462-472.

[19] Memon AN, Hindu AK, Memon NA, Amur MA, Hussain U  Potential of Waste Plastic (PET) Bottles Strips as Reinforcement Material for Clayey Soil.

[20] Patil A, Waghere G, Inamdar N, Gavali P, Dhore R, Shah Sh 2016 *International Journal of Engineering Research* **5**(1) 290-292.

[21] Gangadhara S, Bharath VS 2017 *International Journal of Latest Technology in Engineering Management & Applied Science* VI(IV) 127-133.

[22] Alshkane YM 2017 *Iraqi Journal of Civil Engineering* **11**(2) 45-54.

[23] Pal S, Maity J, Chattopadhyay BC 2018 *International Research Journal of Engineering and Technology* **5**(3) 2158-2161.

[24] Khan FH, Pachghare AM 2015 *International Journal of Advance Engineering and Research Development* 2 (5).

[25] Laskar A, Pal SK 2013 *Electronic Journal of Geotechnical Engineering* **18** 1547-1558.

[26] Paramkusam BR, Prasad A, Arya CS 2013 *International Journal of Structural and Civil Engineering Research* **2**(3) 232-240.

[27] Jin DC, Kalumba D, Chebet FC 2019 Laboratory Investigation of Recycled Polyethylene Terephthalate (PET) as Soil Reinforcement Material.

[28] Mahali KP, Sinha AK 2015 *International Journal of Research in Engineering and Technolog* **4**(6) 29-35.

[29] Phonsa R, Singh H 2019 *International Journal of Innovative Technology and Exploring Engineering* **8**(7) 1627-1629.

[30] Solanki P, Bhattarai S 2019 *Fifth International Conference on Sustainable Construction Materials and Technologies*.

[31] Manicknam N, Bhavan PS, Santhanam P, Muralisankar T, Kumar SD, Balakrishnan S, Devi AS 2020 *Acta Ecologica Sinica* **40**(1) 81-89.

[32] Hotti S, Kadabi SA, Kuchabal B, Koganur K, Padaganur V 2019 *International Journal of Technical Innovation in Modern Engineering & Science* **5**(6) 277-282.

[33] Karmacharya R, Acharya IP 2017 Reinforcement of Soil Using Recycled Polyethylene Terephthalate (PET) Bottle Strips, *Proceedings of IOE Graduate Conference*.

[34] Gangadhara S, Ranganath VS 2016 *International Research Journal of Engineering and Technology* **3**(11) 1086-1094.

[35] Vinoth M, Ayyappan A, Keerthana P, Pandiselvi D, Dharshini KP, Radhika S 2018 *International Journal of Emerging Technologies in Engineering Research* **6**(3) 156-161.