Soil Improvement Using Waste Plastic Bags: A Review Paper

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Abstract. Plastic waste is increasing by time that caused huge challenges all over the world. Therefore, there is a need for good ways to solve the environmental challenges. Also, there is another problem which is that many times weak soil faces the projects, the soil needs to be improved. The idea of this paper is to have a thorough review on literature to collect the data on reinforcing soil with waste plastic bags, where the plastic bags strips are reused as a soil stabilizing technique. This solution will be cost effective and eco-friendly and will solve soil weakness problem. This article reviews the works that has been carried out in this issue to find out the functionality of these waste strips as reinforcing material. From this paper the findings were that plastic bags can be used as an effective solution to improve soil strength while being eco-friendly and cost effective. It is noticed that addition of 0-2.5% plastic bags results in getting better property improvements. Regarding the dimensions of the additives it was found that the plastic strips with higher the aspect ratio lead to better test results. Finally, CBR, shear strength parameter and compaction characteristics of stabilized samples were visibly improved comparing to non-stabilized samples.

1. Introduction

Soil is an important construction material and is commonly used in all forms of construction. All types of structures are founded on foundation that essentially rests on soil. The foundation is very critical for any land-based system, and must be solid to sustain the whole system. The soil around it plays a very critical role, so that the foundation is strong. So we need to have proper knowledge about their properties and factors that affect the behavior, to work with soils, the soil stabilization method helps to obtain the quite properties required for building work in a soil there. The importance of improving soil properties has come to light from the outset of building work [1].

Soil stabilization is the process which improves the soil's engineering properties and makes it more stable. The stability and reliability of geotechnical structures can be achieved through soil strengthening by random distribution throughout the soil mass [2]. Soils are usually stabilized to improve strength and resilience, or to avoid the development of erosion and dust [3]. The key goal is to establish a soil substance or method that will hold for the engineering project under construction usage conditions and the built life [4], [5], the basic concepts of soil stabilization are: to evaluate the properties of the soil, to decide the lack of soil property and to select an efficient and inexpensive form of soil stabilization, to develop a stabilized soil mix for the stabilization and stability qualities expected. [17], there are two types of soil stabilization techniques, Mechanical stabilization: Where the stability of the soil is
increased by blending the available soil with imported soil or aggregate, in order to obtain the desired particle size distribution and to compress the mixture to the desired density. Compacting a soil to a suitable moisture content is a method of mechanical stabilization itself. Chemical stabilization: Adding or injecting contaminants such as lime, asphalt, sodium silicate, calcium chloride, bituminous materials and resinous materials with or in the soil may improve the soil’s stability. Chemical stabilization is the general term which means the use of chemicals to achieve stabilization.

The widespread increase in day-to-day consumer applications of single-use plastics continues to contribute to an ever-increasing volume of plastic material generated in municipal solid waste worldwide. Landfills are often constantly loaded with recycled waste that has been used for just a limited period, with more than 50 per cent of the plastics discarded resulting from packaging products, a portion of which consists of plastic shopping bags [6]. Made of polyethylene, a non-biodegradable polymer, plastic shopping bags are low-cost, lightweight, durable and water-resistant, making them a convenient and reliable packaging material for consumers around the world [7]. After their initial appearance about 50 years ago, shopping bags made of plastic (polyethylene) have been used widely. Finding a solution to this non-degradable polyethylene waste is key to a sustainable environment with landfills rapidly filling in [8]. There are also environmental issues around the world, so it's a good idea to use waste materials as soil stabilization, as it will reduce waste and stabilization prices. Use of plastic products for example plastic bags. It rising day by day contributing to various environmental issues. The disposal of the plastic waste without causing any ecological hazards has therefore becomes a real challenge. The use of plastic waste as a soil stabilizer is therefore an economical use, as there is a lack of good quality soil for embankments [9]. This approach will lead to improved and longer lasting charging power systems. This approach also aims to address the various societal problems, such as minimizing the volume of waste, generating usable products from non-useful waste materials and others. It can be used efficiently to improve the embankment soils, to prepare an appropriate base for upper pavement structure, etc. [10]. The use of plastic strips in geotechnical applications is one of the best strategies for improving the soil’s engineering properties and regulating the amount of plastic waste to use this plastic waste to enhance the soil’s engineering properties by reinforcing soil by plastic strips [11]. Usage of polyethylene waste plastic bags for soil stabilization has also been rendered in various geotechnical infrastructure applications such as road bases, embankments and slope stabilization. The random mixing of plastic waste with soil results increases weak soil bearing capacity, reduces soil settlement, provides lateral stability and increases liquefaction resistance [12]. The aims of any stabilization strategy used are to improve soil strength, resilience, erosion control, strengthen the workability, and buildability. Stabilization for any given soil can be effective in improving the soil properties rather than scraping and replacing the material. Variable from which the stabilizing agent is chosen can often be decided by the availability or financial consideration [11]. The objective of this paper is to make and carry out a literature review to find the effectiveness of plastic bags strips in improving the soil properties and to find whether it worth it to be used or not. And also to find the good percentages and aspect ratios to be used later in other studies and this will ease the process find the optimum dimension and percentages.

1.1. Problem Statement

• Despite fast technical developments internationally, the use of plastics like plastic bags, bottles etc. is also growing. Where, around 500 billion bags are being used every year in the world [13]. Disposal of threw waste poses a significant problem because most plastic waste is non-biodegradable and unfit for incineration because it releases toxic gases. [14]
• Soil stabilization improves the engineering properties of fragile soils by managed compaction or the application of stabilizers such as asphalt, lime, etc. but these additives have often been costly in recent years [14].
1.2. Solution Statement and Aim
• Provide an alternative plastic waste management solution.
• Provide a cost-effective soil stabilization solution using plastic waste. Trash is safe, just need to be recycled.
• It will protect the environment as it is Eco-friendly.
• Increase shear resistance, soil tensile strength by decreasing soil compressibility.

2. Literature Review
During the recent years, various studies have been conducted on reinforcement of soil by using plastic bags. Some of them are discussed in below:
Kalumba (2010). In this study a sandy soil was reinforced by plastic bags strips of dimensions; 6 x 15 mm, 6 x 30 mm, 6 x 45 mm, 12 x 15 mm and 18 x 15 mm. and percentages of 0.1, 0.2 and 0.3% by mass of soil were adopted, where, direct shear test was carried out and it was found aspect ratio 0.4 was the best dimensions and 0.3% was best percentage. Where Increase of more than 20% in angle of internal friction. And the soil shear strength improved with increased strip length and there is significant improvement in the strength of soils because of increase in internal friction [16].

In study of Ali et al. (2019), silty sand (A-2-4 soil) was reinforced with 10 different Poly Propylene plastic bags varying in weight are utilized and placed in layers to prepare the soil-plastic composite specimens. Where the 10 different weights were (0, 50, 100, 150,200,250,300,350,400,450) g/m2. The tests employed to analyze the behaviour of plastic reinforced soil are Modified Proctor Compaction tests and California Bearing Ratio tests under un-soaked and soaked conditions. From the results it was observed that as weight of Plastic bags increases, the optimum moisture content increases and maximum dry density decreases. Un-Soaked CBR tests, it is found that the sample with plastic bags of weight of 150 g/m2 gives maximum value. After this point, decreasing trend starts. And in the case of under Soaked Condition, it is observed that the value of CBR increases with increase in weight of plastic Bags. The highest value is obtained at 190 g/m2 [17].

In Shiva Kumar et al. (2016) study, plastic strips were added to black cotton soils and the sample were tested for carrying unconfined compression test and CBR. The strips were added in various percentages by dry weight (0.05%, 0.1%, 0.15% and 0.2%) with dimensions of 3 mm x 20 mm. It was found that at 0.2% plastic the max dry density is only 0.1% more than plain clay soil and is achieved at similar water content when compared to clay soil. But it is observed that beyond 0.2% plastic the decrease in max dry density with increase of optimum water content. The unconfined compressive strength for clay soil is increased due to inclusion of plastic waste strips the strength of the soil is increased up to addition of 0.2% of plastic strips. The California bearing ratio values are increasing with the increase in percentage of waste plastic strips and it was found CBR increased about 192 % at 0.2% [11].

Chebet and Kalumba (2014) research included a laboratory investigation on reinforcing sand with strips of high-density polyethylene material from plastic shopping bags. Direct shear tests and plate loading tests was conducted on soil-plastic composites of 2 selected sandy soils. Fibers were used as reinforcement at percentages of up to 0.3% by weight. The influence of changing dimensions of the fibers was investigated by using normal strip of dimensions strip lengths from 15 mm to 45 mm and strip widths from 6 mm to 18 mm and perforated plastic strips of diameters 1 mm and 2 mm on strips of constant width 6mm with lengths of 15 mm, 30 mm and 45mm. It was found that increase around 10% in angle of internal friction and also bearing capacity of soil increase around 35% and improved of soil shear strength was observed at 0.3 % and dimension 6mmx15mm [7].

In Arpitha et al. (2017) shopping bags were used to reinforce clay soil and a series of California Bearing Ratio (CBR) tests were carried out on randomly reinforced soil by varying percentage 0.5%, 1%, 1.5%, 2%, 2.5% of plastic strips by weight of soil, with different lengths and proportions. CBR was improved by adding of waste bags strips in soil with appropriate amounts improved strength and deformation behavior of sub grade soils substantially. Also, from the results obtained after performing the test with plastic bag strips that 2% of the total weight of the soil is the optimum proportion of strips cut from
waste bags to be included to the soil as reinforcement. But it decreases when furthered amount of plastic bags strips is added [18].

Agarwal et al. (2015) used expansive soil that was reinforced with plastic bags, with dimensions of 1 cm * 1 cm, 2 cm * 2 cm, 3 cm * 3 cm, 4 cm * 4 cm, and percentages of 0.05%, 0.1%, 0.15% and 0.2% by mass of soil, and CBR test was carried out. It was found that the most favorable ground stabilization condition could be achieved when plastic bag pieces of size 2 cm * 2 cm were used at a proportion of 0.1%. Under this condition the value of CBR was found increased around 43% than the soil without plastic bags [19].

Pandit et al. (2016) investigated the possibility of utilizing polyethylene shopping bags waste to reinforce soil to improve the compaction characteristics of soil. The plastic strip of width 10 mm and 15 mm and lengths 20 mm, 40 mm, 60 mm are mixed with the clay soil by 0.15%, 0.30%, 0.45% and 0.60% by the mass of soil. It was found maximum dry density increase around 9% at 0.3% with aspect ratio 2 [8].

In work of Chakraborty et al. (2018), the study was undertaken to evaluate the effects of the waste plastic polyethylene on the geotechnical properties of two locally available sands (Brahmaputra and Kulsi sand). And a series of direct shear tests on the two sand samples reinforced with polyethylene plastic strips were conducted. The influence of changing percentage of bags (0.10%, 0.20%, 0.30%, 0.45%, 0.60%, 0.70% and 0.75%) by weight using various dimensions of the bags strips is studied. The polyethylene plastic bags strips’ length varied from 15 mm to 45 mm and width varied from 5 mm to 15 mm. The friction angle of both the Brahmaputra and sand increases with the inclusion of plastic strips to the soil. The friction angle for the Brahmaputra sand attained a maximum value at 0.6% concentration of plastics. 0.6% percentage of bags is the best percentage of plastics and also the aspect ratio 3 is the optimum aspect ratio giving the maximum friction angle. The friction angle for sand reached a maximum value at 0.3% of the concentration of the plastics strips, which is the optimum concentration of plastics. Also the aspect ratio of 3 is found to be the optimum aspect ratio giving the maximum friction angle [14].

Mishra and Babu (2017) worked on red soil that was reinforced with plastic products such as polythene bags. Waste house hold plastic bags were used to carry out these experiments. Plastic bags percentage such as 0 %, 0.25 %, 0.50 %, 0.75 %, 1.00 % and 1.25%. The highest value observed being at plastic content 1% by weight of the soil taken. Maximum dry density shows a decrease to 0.75% inclusion of waste bags more reaches maximum at 1.0% of plastic waste and more decreases. The CBR was maximum when the waste bags percentage was 0.75%, more increase in waste bags reduced the CBR value. In direct shear the Cohesion (C) and Angle of Internal Friction (Φ) value was maximum when the waste plastic content was 1.0% Where C was 75% increased and Frictional angle 67 % increased [20].

Subba Reddy et al. (2018), presents a laboratory investigation into the resultant increase in shear strength and bearing capacity of locally sourced sand due to random inclusion of strips of high-density polyethylene material from plastic shopping bags. Direct shear tests was conducted on soil-plastic composites of 2 sandy soils. Fibers of shredded plastic bags were utilized as enhancement additions at percentages of up to 0.3% by weight. The influence of changing dimensions of the fibers was studied by using fibers lengths from 15 mm to 45 mm and fibers widths from 6 mm to 18 mm. From the direct shear test results, an enhancement of more than 20% internal friction angle was attained in the sandy soils implying an increase in the shear strength on inclusion of the plastic fibers. Perforations of diameters 1 mm and 2 mm were used in the plastic fibers to study any enhancements in the shear strength of the soil as a result of this modification. By adding perforated fibers of dimensions and percentages in soil, more enhancement in friction angle was shown. the best length 15 mm, percentage 0.1% and perforation diameter of 2 mm for fibers widths of 6 mm [21].

In Dikkar et al. (2017) study, utilization of polyethylene shopping bags waste used for improvement of soil properties. The plastic fibers dimensions of lengths 20 mm, 40 mm, 60 mm and width 10 mm and 15 mm are mixed with the black cotton soil by 0.15%, 0.30%, 0.45% and 0.60% by the weight and standard proctor, Unconfined strength test and CBR tests are carried out. It was found that the UCS value increases with increase % of plastic strips from 0% to 0.3%. CBR improved with increase in
content of bags fibers from 0 to 0.30% and further increase in plastic strip causes decrease in CBR value. So it can be concluded that 0.30% of plastic strips is optimum percentage to be used as a stabilizing agent for sizes 10mm x 40mm and 15mm x 40mm [22].

Chebet and Kalumba (2015) added fibers to soil and a testing program consisting of large direct shear and small direct shear tests were undertaken on soil-plastic composite samples comprising of sand mixed with strips of plastic material. Plastic strips with varying lengths of 15 mm, 30 mm and 45 mm at concentrations of 0.1%, 0.2% and 0.3% by mass were added to samples of oven dried sand. The samples were oven dried at 105º C for 24 hours to eliminate any effects due to changes in moisture. Different responses of the sand to the inclusion of the plastic were observed as the plastic strip parameters of length, width and concentration were varied. The parameters that resulted in maximum increase in the friction angle were considered as optimum for the range of tests undertaken. From the experiments conducted, for large shear box optimum results were obtained from strips of length 15 mm, width of 18 mm and concentration of 0.1%. For the smaller shear box, optimum results were from strips of length 15 mm, diameter 6 mm and concentration of 0.3%. This variation can be attributed to effects of scale in the smaller box. However, the overall result attained from the tests was an increase of over 20% in friction angle indicating an improvement in the shear strength on addition of the plastic strips [23].

Saha et al. (2017) presented the stabilization of cohesive soil using randomly distributed waste plastic bags at varying lengths (1cm x 1cm, 1cm x 2cm and 1cm x 4cm) and percentages (0.5%, 1% and 1.5%) by weight of cohesive soil. CBR and Standard Proctor tests were conducted to investigate the behavior of clayey soil mixed with waste plastic bags. From the test results, it was seen that increase in percentage of waste bags in soil, maximum dry density decreases whereas optimum moisture percentage increases. But, the strength values of the composite at optimum moisture content, improved with increase in percentage of waste plastic bags up to a certain limit. CBR values of the soil waste bags enhances with increase of percentage of waste bags and reaches maximum values at 1% of 1cm x 1cm size and after that it decreases with further inclusion of waste plastic bags within the range of testing programme [12].

The Chebet and Kalumba (2013) study investigated the possibility of utilizing polyethylene shopping bags waste to reinforce soils to pave way for its use in civil engineering projects such as in road bases, embankments and slope stabilization. Direct shear tests was conducted on soil of 2 sandy soils. Fibers of shredded plastic fibers were used as reinforcement addition at percentages of up to 0.3% by weight. Dimensions (15-45) mm lengths and (6-18) mm widths. Laboratory results obtained favorably suggest that addition of this fibers in sandy soils is effective for ground enhancement in properties [24].

Vismaya et al., (2019) investigated the possibility of utilizing plastic bag waste for the reinforcement of soils. The various thickness ranges used were 15μm, 30μm, and 45μm and dimension of 12 mm x 30 mm and waste plastic bag strips were added at 0.1%, 0.2% and 0.3% concentration. The maximum value of UCS is obtained for soil reinforced with 0.2 % plastic content having an aspect ratio of 2.5. Soil stabilized with plastic strips of thickness 45μm is having maximum compressive strength [25].

Rajkumar (2014) added fibers to black cotton and yellow soil and sandy soils. Their study proved that maximum dry density and CBR value increases with increase in plastic waste. Load bearing capacity and settlement characteristics of selected soil material are also improved [26].

In Chebet et al., (2012) research, a series of direct shear tests were conducted on plastic reinforced soil specimen prepared using two sandy soils and random inclusions of perforated plastic strips obtained from high density polyethylene shopping bags. The influence of the perforated plastic inclusions on the shear strength parameters of the soil was investigated. The study also examined the effect of increasing concentration, varying length of the strips and the diameter of perforations on the strips. The fibers were included to the soil samples at percentages of 0.1%, 0.2% and 0.3% by weight. Strip lengths of 15 mm, 30 mm and 45 mm, and diameters of perforations of 0 mm, 1 mm and 2 mm were selected for the study. There was an enhancement in friction angle by inclusion of the perforated fibers of different dimension and percentages for soils. The best length 30 mm, percentage 0.1% and perforation diameter of 2 mm. increasing the diameter of perforations on the plastic fibers resulted in higher friction angle with increases of 2◦ for every 1 mm in perforation diameter [27].
2.1 Advantages of Soil Improvement Using Plastic Waste [10], [15]
- Reduction of the permeability of soil.
- Improvement in load bearing capacity.
- Increase in the shear strength of soil.
- Enhancement in durability.
- Cracks and swelling reduction.
- CBR improvement.
- Settlement reduction.
- Helps in solving the issue of plastic waste.
- Cost-effective and energy intensive for enhancing soil quality.
- Available in abundance

Table 1. Properties of soil reinforcement with different plastic bags strips percentages

| % of Plastic bags by soil mass | CBR % | Direct Shear % | MDD % | OMC % | UCS % | Bearing Capacity % | Reference |
|-------------------------------|-------|----------------|-------|-------|-------|---------------------|-----------|
| 0.05                          | +(3-21) | +0.5          | +3    | -10   | -6    | +7                  | [11,7,19,14] |
| 0.1                           | +(45-178) | +(6-24)       | +2    | -6    | +(80-110) | +28.5              | [16,11,7,19,21,23,25,27] |
| 0.15                          | +(27-177) | +1.5          | +(1.8-2) | - (0.4-7.8) | +(100-147) | +49                | [7,8,11,19,22] |
| 0.2                           | +(15-191) | +(9-23)       | +0.6  | +1.6  | +(127-240) | +56                | [7,16,11,19,21,23,25,27] |
| 0.25                          | +68    | +23           | +6.6  | -19   | -     | +62                | [20,21,23] |
| 0.3                           | +235   | +(9-26)       | 0     | 0     | +(140-321) | +71               | [16,7,8,21,22,23,25,27] |
| 0.45                          | +79    | +10           | +0.3  | -4    | +96   | -                  | [8,14,22] |
| 0.5                           | +(3-166) | +(0.5-9)      | (-1)-(+5) | (-12)-(+29) | -     | -                  | [18,14,20,12] |
| 0.6                           | +15    | +7.4          | +1.7  | -7.7  | +103  | -                  | [8,14,22] |
| 0.75                          | +227.8 | +18           | +1.98 | +13.95 | -     | -                  | [20] |
| 1                             | +(4.9-180) | +6          | (-1)-(13) | -     | -     | -                  | [18,20,12] |
| 1.25                          | +160   | +15           | +4.9  | -11.4 | -     | -                  | [20] |
| 1.5                           | +(7-98) | -1.85         | +38   | -     | -     | -                  | [18,12] |
| 2                             | +0.7   | -             | -     | -     | -     | -                  | [18] |
| 2.5                           | +0.6   | -             | -     | -     | -     | -                  | [18] |

3. Conclusion
- The conclusions below may be drawn from the study:
- Results of various researchers give positive indication to the possibility of using the plastic waste bags for reinforcement and stabilization of soil.
- The use of plastic waste bags has significantly helped in ground improvement.
- Adding plastic bags to soil is an economical solution.
• There is considerable increase in CBR value. As the material is waste and biodegradable therefore can be suggested to use for the construction of roads like village roads, temporary roads etc.
• The inclusion of plastic bags to the clay soil causes a reduction in the maximum dry unit weight and an increase in the optimum moisture content. With an increase in plastic bags strips the optimum moisture content has a decreased.
• The effect of plastic waste in improving soil properties mainly depends on strip size, plastic content and the type. The plastic strips provides a good enhancement method for soil.
• The optimum percentage of plastic bags strip is (0-2.5 )%
• The higher the aspect ratio the better the results.

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