

Stabilization of Soil by Using Waste Plastic Material: A Review

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ABSTRACT: Infrastructure is a major sector that propels overall development of Indian economy. 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. Expansive soils like black cotton soil always create problems in foundation. The problems are swelling, shrinkage and unequal settlement. Plastic wastes have become one of the major problems of the world. Use of plastic bags, bottles and other plastic products is exponentially increasing year by year. Due to which we are facing various environmental problems. A review paper is presented here to focus on soil stabilization by using 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 black cotton soil.

KEYWORDS: soil stabilization, California bearing ratio, unconfined compressive strength, Black cotton soil.

I. INTRODUCTION

Industrial development in India has necessitated construction of infrastructure facility such as highways, airports seaports and residential, commercial buildings. There is a need to select a good soil conditions for proper safety consideration of all these projects. Such soils exhibit extreme stages of consistency from very hard to very soft when saturated. Expansive soils contain minerals that are capable of absorbing water. They undergo severe volume changes corresponding to changes in moisture content. They swell or increase in their volume when they imbibe water and shrink or reduce in their volume on evaporation of water (Chen 1998). Because of their alternate swelling and shrinkage, they result in detrimental cracking of lightly loaded civil engineering structures such as foundations, retaining walls, pavements, airports, side -walks, canal beds and linings (Chen 1988).

Due to these reasons expansive soils are generally poor material for construction. So to improve the engineering properties of soil, stabilization or reinforcement is done. Soil stabilization is the process of blending and mixing materials to improve engineering properties of soil like increasing shear strength, compressibility and permeability, thus improving load bearing capacity of a sub-grade to support pavements and foundations. For many years, engineers have used traditional additives such as lime, cement and cement kiln dust etc. to improve the qualities of readily available local soils. The stabilization of expansive soils with cement and lime is well documented. Cement stabilization nowadays is less appreciated because of the increasing cost of cement and environmental concerns related to its production. India being the second largest producer of cement has a very heavy impact on CO₂ emission. One can imagine from the fact that approximately one tone of CO₂ is produced during the production of one tone of cement. On the other hand, lime also contributes CO₂ to the world climate during its production. The cost of these additives has also increased in recent years. This has opened the door widely for the development and introduction of other soil types of additives, such as plastic, bamboo, stabilization liquid enzyme soil etc. open.

Plastics are inexpensive, lightweight and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. On an average, an Indian uses 1 Kg of plastics per year and the world annual average is an alarming 18 kg. As per data available on Municipal Solid Waste (MSW) 2009, approximately, 4000-5000 ton per day plastic wastes are generated. As a consequence, the production of plastics has increased

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markedly over the last 60 years. Today, every vital sector of the economy has been virtually revolutionized by the application of plastic. According to recent studies, plastic can stay unchanged for as long as 4500 years on earth. Use of this non-biodegradable product is growing rapidly and the problem is what to do the plastic waste. Several million metric tons plastic wastes are produced every year. Natural materials being exhaustible in nature, its quantity is declining gradually. Also, cost of extracting good quality of natural material is increasing. Concerned about this, the scientists are looking for alternative materials for soil stabilization, and plastic wastes product is one such category. To deal with the growing disposal problem of these materials is an issue that requires co-ordination and commitment on the part of all parties involved such as government agencies, companies, the public and professionals. One method to reduce some portion of the plastic waste disposal problem is by recycling and utilizing these materials in the stabilization of expansive soil.

Therefore, for sustainable development use of locally available plastic waste materials should be encouraged. The objective of this study was to make economical and to maintain environmental balance, and avoid problems of waste plastic disposal i.e. the use of plastic waste for stabilization of black cotton soil and its possible combined utilization with various proportions to obtain maximum stability.

II. DATA ON GENERATION OF PLASTIC WASTE AND PLASTIC COMBUSTION

In 2013 consumption of plastic in India was about 120 lakh tons but it is about to reach 200 lakh tones by the year 2020 due to growing use of different forms of commodity. The consumption of plastic in different forms is increasing by an average of 10% every year. Rate of generation of plastic wastes in Indian cities ranges between 0.20-0.87 kg/day, depending upon the size of the city and living standard. Every year about 8 million tons of plastic waste is dumped in to the world's oceans. Table-1 shows different types of plastic wastes and their sources.

Table-1.Waste plastic and its sources

Waste plastic	origin
Low density polyethylene	Carry bags, sacks, milk pouches, bin lining, cosmetic and detergent bottles
High density polyethylene (HDPE)	Carry bags, bottle caps, house-hold articles.
Polyethylene Terephthalate (PET)	Drinking water bottles etc.
Polypropylene(PP)	Bottles caps and closures, wrappers of detergent, biscuit and wafers packets, microwave trays for meal etc.
Polystyrene(PS)	Yoghurt pots, clear egg packs, bottle caps. Foamed polystyrene: food trays, egg boxes, disposal cups, protective packaging etc.
Polyvinyl chloride(PVC)	Mineral water bottles, credit cards, toys, pipes, and electrical fittings, furniture, folders and pens, medical disposables etc.

III. LITRATURE REVIEW

S.W. Thakare and S. K. Sonule, (2013) carried out various laboratory tests to investigate the effect of reinforcement of sandy soil with model plastic water bottle through model plate load tests. The study showed that the ultimate bearing capacity of footing increases with increasing the layer of plastic bottles as reinforcement. The increase in bearing capacity may be due to the additional confinement to the soil in the vicinity of footing similar to that in case of Geocell. The bearing capacity increases with the increase in width of reinforcement and number of layers. Thus, the use of plastic bottles as reinforcement was recommended to reduce the quantity of plastic waste which creates the disposal problems.

Harish and Ashwini, H.M. (2016) studied the effect of plastic bottles strips as a stabilizer for two soil samples, red soil and black cotton soil. Red soil consists of 4 % gravel, 88% sand and 8% silt and clay and black cotton soil 2.6% gravel,

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15.1 % sand and 82.3 % silt and 0.18 % of clay. They used plastic stripes in making the pavement and it was found that there was an increase in the strength of the soil. Authors conducted a CBR ratio test to find out MDD and OMC. They observed an increase in the strength of soil and bearing ratio of 2.9 for red soil and 3.3 for the black cotton soil by mixing 0.7 % of waste plastic strips to red soil and 0.5 % for the black cotton soil.

Jasmin Varghese Kalliyath *et.al.* (2016) studied the effect of plastic fibers. Various tests such as Standard Proctor, UCC were carried out with different samples of silty clay. Authors observed that the replacement of 0.5 % waste plastic fiber to the expansive clayey soil reduce its OMC and increased maximum dry density but UCS of the soil was found to be increased. The test results also showed that with 1% replacement, MDD and UCC were less than the 0.5 % replacement but greater than the untreated soil. Further increase in the plastic replacement showed decrease in the MDD and the UCS. The increase in the MDD of the soil with 1% replacement is due to the decrease in the number of voids with the addition of plastic which leads to effective compaction and also increase in the cohesion. Thus authors concluded that optimum percentage of plastic was 0.5 % for optimum results.

Mercy Joseph Poweth *et al.* (2014) investigated the effect of plastic granules on weak soil sample with plastic and without plastic granules in varying percentage. The percentage of waste plastic was taken as 0.25%, 0.5 %, 0.75%. Maximum dry density was obtained when 0.25 % plastic was added and OMC was less than the soil without plastic for this percentage of soil. Further CBR value decreases when 0.25 % plastic is added but it was found to be increased for 0.75 % of plastic. Authors also observed that for the same percentage of plastic, shear stress was maximum.

Satyam Tiwari and Nisheet Tiwari (2016) investigated the effect of waste polypropylene fiber on shear strength of unsaturated soil samples. Here, the percentage of specific gravity of the soil increases 0.3% by using 0.5% of fiber (PPF).

Table-2: Results of the experiments

	Sample 01	Sample 02	Sample 03
Specific gravity of soil without fiber	2.6315	2.65	2.6842
Specific gravity of soil with fiber	2.64	2.655	2.6895
Liquid limit of soil without fiber	40.33%	47.05%	45.31%
Liquid limit of soil with fiber	43.89%	36%	41.80%
Plastic limit of soil without fiber	28.68%	29.67%	29.72%
Plastic limit of soil with fiber	22.35%	28.14%	27.03%
Shrinkage limit of soil without fiber	3.029	2.97	2.94
Shrinkage limit of soil with fiber	5.65	6.1	5.46

Table-2 shows the variations in the optimum moisture contents, maximum dry density, California bearing ratio, unconfined compressive strength.

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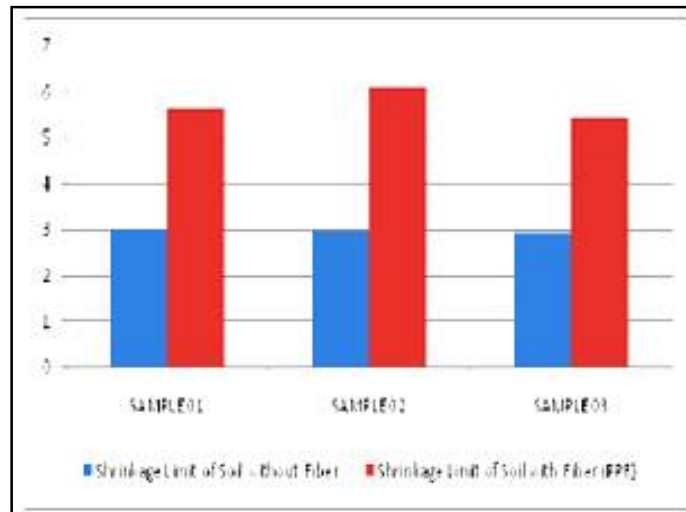


Fig.1: Graph showing Shrinkage limit of soil without reinforcement and with reinforcement.

The value of shrinkage limit of unreinforced soil is less than the reinforced. Lesser the shrinkage more will be suitability of soil for foundation, road and embankments due to more strength.

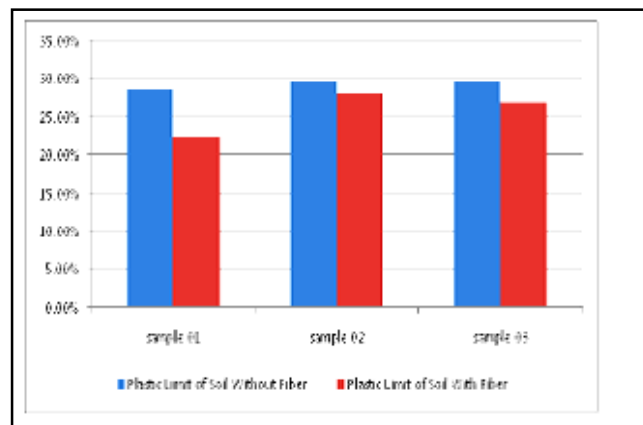


Fig.2: Graph showing liquid limit of soil without reinforcement and with reinforcement.

From the fig.2, it is evident that liquid limit increases on reinforcement. The difference of liquid limit without reinforcement and with reinforcement was 18.18%.

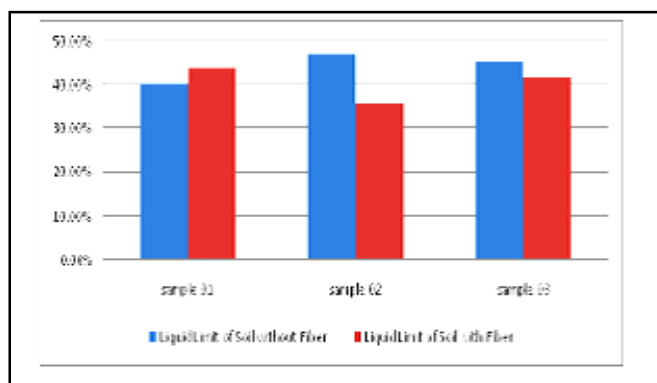


Fig.3: Graph showing Plastic limit of soil without reinforcement and with reinforcement.

It reduces with reinforcement, and decrease in plastic limit was 12%. This shows increase in shear strength, cohesiveness and consistency in soil mass.

Chebet *et.al.* (2014) conducted experiments to determine the increase in shear strength and bearing capacity of two samples of locally available soil due to random mixing of strips of high density polythene material from plastic shopping bags. Strips of shredded plastic material were used as reinforcement inclusions at concentration of up to 0.3% by weight. These results indicate that the increased strength of soil was due to tensile stresses mobilized in the reinforcements.

Achmad Fauzi *et.al.* (2016) used two soil samples R2 and R24 collected from various sites of KUANTAN. Waste cutting HDPE and crushed waste glass were used as additives. The variations of additive contents were 4%, 8 %, 12 % by dry total weight of soil sample respectively. They evaluated engineering properties like sieve analysis, Atterberg limit, Specific gravity, Standard Compaction, soaked California bearing ratio and tri-axial test of the soil sample before stabilization and after stabilization. The result showed that on addition of waste HDPE and glass there was an increase in PI, about 10% for R24 and 2% for R2 samples respectively. The value of optimum water content decreases and MDD increases when content of waste HDPE and glass were increased but there was an increase in CBR value. Authors also observed that there was a decrease in the value of cohesion and increase in friction angle of R2 and R24 samples with additives.

A.I.Dhatrak *et.al.* (2015) calculated the engineering properties by mixing waste plastic. It was observed that for construction of flexible pavement to improve the sub grade soil of pavement using waste plastic bottles chips is an alternative method. In a proportion of 0.5%, 1%, 1.5%, 2%, and 2.5% of the weight of dry soil, plastic waste was added to calculate CBR value. He concluded that using plastic waste strips will improve the soil strength and can be used as sub grade. It is economical and eco-friendly method to dispose waste plastic.

Anas Ashraf *et.al.* (2011) studied on the possible use of plastic bottles for soil stabilization. The analysis was done by conducting plate load tests on soil reinforced with layers of plastic bottles filled with sand. The bottles cut to halves placed at middle and one third position of tank. The test results showed that cut bottles placed at middle position were the most efficient in increasing strength of soil.

Rajkumar Nagle *et.al.* (2014) conducted various experiments to compare CBR of soil reinforced with natural waste plastic. They mixed polyethylene plastic bottles food packaging and shopping bags etc. as reinforced with three soil samples of expansive soil (black cotton soil), silty-clay and sandy soil. Their study showed that MDD and CBR value increases with increase in plastic waste.

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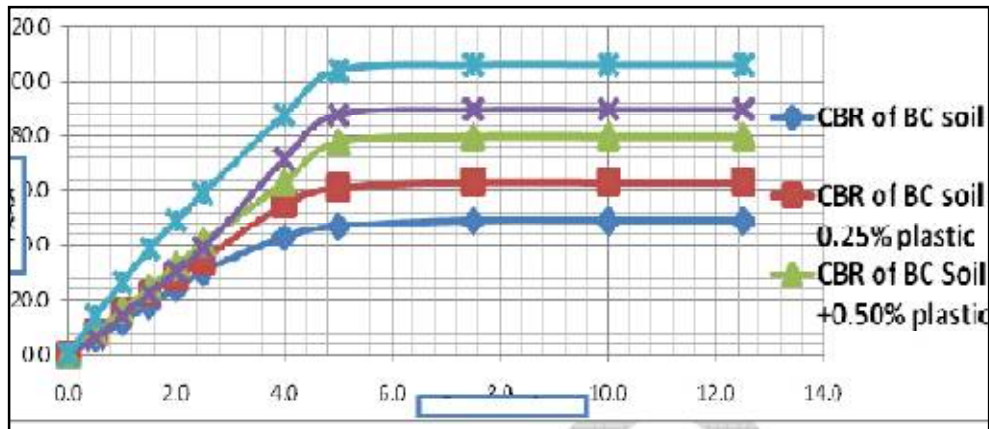


Fig.4 showing behavior of (black cotton soil) soaked CBR values with respect to addition of plastic material in different percentages.

Fig.4. shows that as the percentage of plastic waste in expansive soil increases, MDD increases, thereby increasing the CBR value. The maximum improvement in CBR was obtained on adding 1% plastic waste.

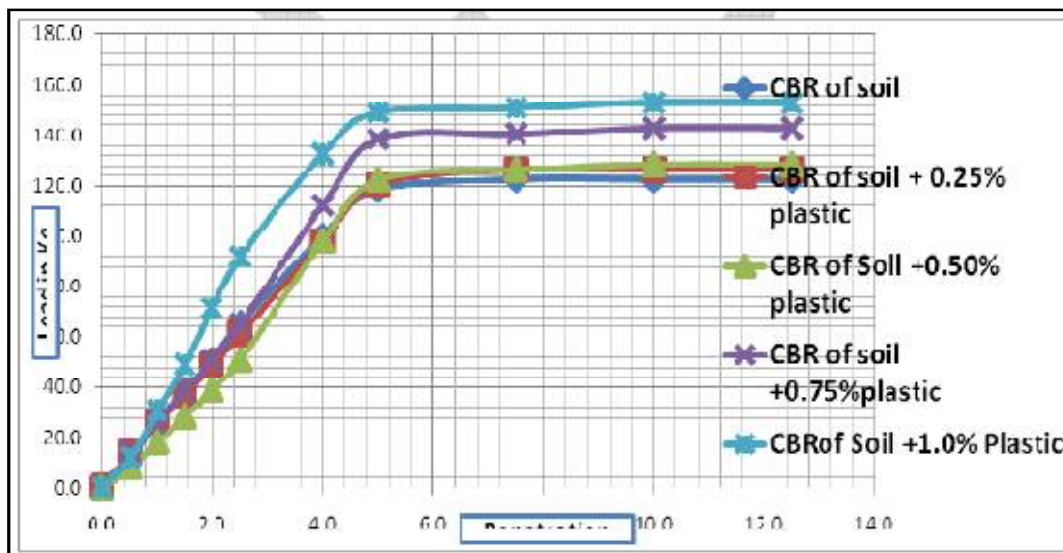


Fig.5. showing behavior of yellow (soaked) soil CBR values with respect to addition of plastic material in different percentages

Fig.5 shows that for yellow soaked soil, increase in CBR value was maximum while using 1 % of plastic waste and CBR value for 0.25% and 0.50% of waste plastic was minimum. The graph also indicates that the maximum CBR value of a reinforced soil was approximately 1.3 times that of unreinforced soil.

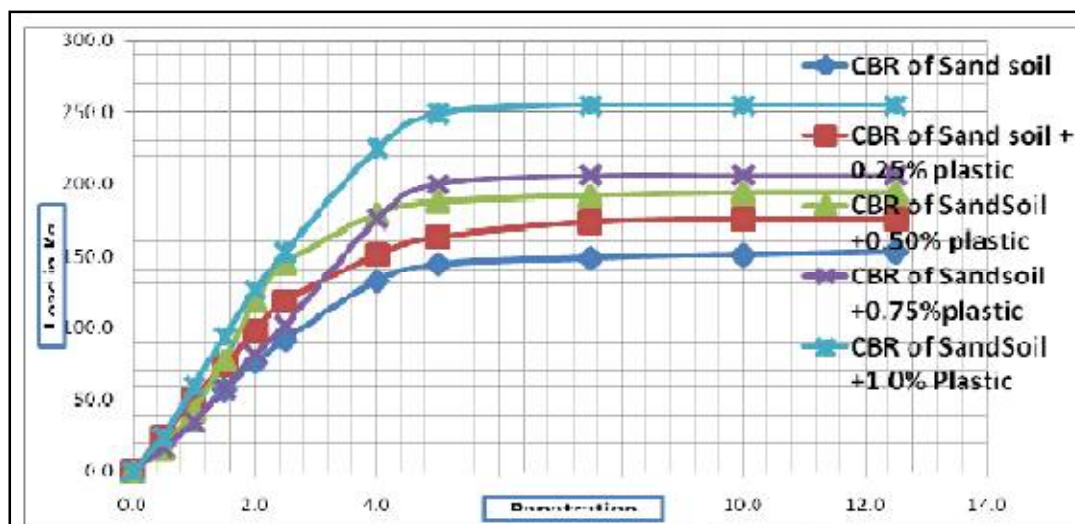


Fig.6. showing behavior of sandy soil (soaked) CBR value with respect to addition of plastic material in different percentage.

Similar results of CBR value were obtained for sandy soil. From the above results, authors concluded that sub-base thickness can be significantly reduced if waste plastic is used as soil stabilizing agent for sub grade material.

Choudhary *et.al.* (2010) performed a laboratory evaluation on utilization of plastic wastes for improving the sub-grade in flexible pavement. In this study the effect of waste plastic strip content (0.25% to 4%) and strip length on the CBR and secant modulus of strip reinforced soil was investigated. The study reveals that addition of waste plastic strip of appropriate size and proportions in soil result in increase in both CBR value and secant modulus of soil.

Bala Ramudu Paramkusam *et.al.* (2013) performed an experimental study to investigate the stabilization effect of waste plastic on dry density and CBR behavior of red mud, fly ash and red mud, fly ash mixed with different percentage of waste plastic (PET) content. Based on light compaction tests, authors concluded that MDD value of the red mud, fly ash mixed with plastic increases as the waste plastic increases till 2%, further increase in plastic waste reduces the MDD value. OMC value remains same in each case. A marked increase in CBR value was also observed on adding 0.5%, 1.0%, 2.0%, of waste plastic and was found to be decreased after inclusion of 3% and 4%. Increase of CBR value indicates that the thickness of pavement can be reduced by addition of waste plastic content up to 2%.

Subhash, K. *et.al.* (2016) conducted experimental study on soil stabilization using glass and plastic granules mixed with varying percentage. Modified Proctor tests were carried out to study OMC and CBR. They concluded that there is a decrease in MDD on addition of glass and plastic in varying percentages. The MDD of 1.53 gm/cc was obtained at 6% of glass and plastic. The maximum OMC was obtained as 22.6% at 6% mixing of additive. Further, an increase in the OMC was observed, maximum value of OMC was obtained as 22.6% at 6% glass and plastic additive with the soil. An increase in the UCS from 0.609 Kg/cm² to 3.023 Kg/cm² which is about 5 times as that of virgin soil. Maximum CBR value was 7.14 %, which is 2 times of CBR of virgin soil.

Akshat Malhotra *et.al.* (2014) demonstrated the potential of HDPE plastic waste on the UCS of soil. In a

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proportion of 1.5 %, 3%, 4.5 % and 6% of the weight of dry soil HDPE plastic (40 micron) waste was added. They concluded that the UCS of black cotton soil increased on addition of plastic waste. When 4.5 % plastic waste was added, 287.32 KN/m² soil strength of the soil was obtained which was more than untreated soil.

IV. CONCLUSION

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

1. The plastic inclusions can improve the strength thus increasing the soil bearing capacity of the soil.
2. Every year a lot of plastic waste is generated and occupied a lot of space. It is necessary to find a solution for this problem. Based on literature, one of the solutions is use of plastic waste in soil reinforcement and stabilization.
3. Results of various researchers give positive indication to the possibility of using the versatile plastic products such as plastic bags, bottles, containers and packaging tapes etc. for reinforcement and stabilization of soil.
4. Disposal of plastic waste without environmental hazards has become a real challenge for our society. Therefore, the use of plastic waste as a soil stabilizer is a cost effective and profitable use.
5. 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 amount 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
6. 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:
 - i. To optimize the percentage of plastic waste content.
 - ii. Large scale test is also needed to determine the boundary effects influence on the test results.

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