Analysis and Modification of Engineering Behavior of Soil Using Plastic Waste Materials

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Abstract Plastic waste management becomes a serious issue all over the world. Dumping of plastic waste on land without treating it degraded the properties of parent material. The main objective of this study is to demonstrate the use of plastic waste for improving properties of soil and soil subgrade underlying by aggregate base which is applicable in construction of embankment and flexible pavement respectively. Waste plastic water bottles converted into plastic strips with an aspect ratio of 6%. The behavior of randomly distributed plastic strip-reinforced soil system and soil aggregate system was observed by conducting soaked CBR test series with different percentage of plastic strips (0%, 0.5%, 1% and 2%). Results of study show that soil reinforced with waste plastic strips has significant increase in CBR values with respect to unreinforced soil in both the cases. The results also reveal that the 1% of plastic strip-reinforced soil system and soil aggregate system show significant improvement in strength.

Keywords Plastic waste · CBR · Soil · Aggregate

1 Introduction

Improvement in stability or bearing capacity of the soil can be achieved by the use of controlled compaction, addition of suitable admixtures, use of waste materials, etc. It is more economical both in terms of cost and in energy to increase the strength of the soil rather than going deep. As day by day infrastructure is developing, along with the growth of the country, there is drastic increase in population. This increased

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population leads the problem of solid waste management. According to CPCB report 2018, out of total solid waste, plastic waste is 8.3 billion tones. The bottled water is the fastest growing beverage industry in the world. It is reported that annual consumption of plastic bottles in the world are approximately 10 million tons, and it grows about 15% every year [CPCB]. Plastic waste disposal is the sensitive issue all over the world. There is urgent need to reuse or recycle the plastic waste. A common problem with recycling plastics is that they are often made up of more than one kind of polymer (heterogeneous character) or some sort of fibers added to the plastics (a composite) to give added strength. This characteristic are helpful for using the waste materials in soil of poor strength to improve geotechnical properties of soil. This study of using raw plastic bottles is an alternative method for the improvement of strength parameters of soil.

1.1 Background Study

Rapid improvements in the engineering world have influence a lifestyle of human beings in utmost extends, but day-to-day activities of mankind are augmenting risk in the environment in the same proportion. Plastic wastes have become one of the major problems for the world. The harmful gas which is being produced by this agent leads to tremendous health-related problems. So, effective engineering implementation of this has become one of the challenging jobs for engineers. Engineer are seeking for astute implementation of these wastes in ample amount, and implementing these wastes in soil stabilization helps to reduce the risk of natural destruction which is caused due to rainfall or other aspect, and also, it aids in reducing the waste in an ample amount. Plastic is considered as one of the major pollutants of environment as it would not decay or cannot be destroyed. So, implementing this for some good purpose helps to reduce its effect also.

Plastic can be one of the materials which can be used as a soil stabilizing agent, but the proper proportion and aspect ratio of it matters in CBR value of soil. Study shows that that benefits of reinforcement increase to certain level and after that it will decrease the strength so careful observation must be done. All this shows that plastic strips can be used as a reinforcing material in stabilization of the sub grade soil if used in right proportion [1].

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 [9].

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 was 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 [10].

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 [11].

Anas Ashraf (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 [12].

Rajkumar Nagle 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), silt clay and sandy soil. Their study showed that MDD and CBR value increases with increase in plastic waste [13].

2 Experimental Program

2.1 Materials

Soil: Soil sample used has been collected from big bazaar near vesu Surat. Soil is classified as CH the soil.

Waste Plastic: For making the plastic chips collecting the plastic waste bottles and for the experiment work, cut it by proper size and 6 aspect ratios. Approximate percentage of plastic chips is between 0%, 0.5%, 1%, and 2%. At the time of the CBR test, plastic chips are mixed in very proper manner; thus, soil is not changing.

Aggregate: Aggregates are used as it passes through the 10 mm sieve and retains on 6.5 mm sieve.

2.2 Compaction Test

Compaction test of soil is carried out using Proctor's test to understand compaction characteristics of different soils with change in moisture content. Compaction of soil is the optimal moisture content value 23.797 at which a given soil type becomes most dense and achieves its maximum dry density value 14.130 by removal of air voids.

2.3 California Bearing Ratio (CBR) Test

It is the ratio of force per unit area required to penetrate a soil mass with standard circular piston at the rate of 1.25 mm/min to that required for the corresponding penetration of a standard material.

2.4 Aggregate Impact Test

The aggregate impact test is carried out to evaluate the resistance to impact of aggregates. Aggregates passing 12.5 mm sieve and retained on 10 mm sieve is filled in a cylindrical steel cup of internal diameter 10.2 mm and depth 5 cm which is attached to a metal base of impact testing machine.

$$\text{Aggregate impact test } (\%) = 15.18 < 30 \text{ (satisfy)}$$

2.5 Abrasion Value Test

The principle of Los Angeles abrasion test is to find the percentage wear due to relative rubbing action between the aggregate and steel balls used as abrasive charge.

Los Angeles machine consists of circular drum of internal diameter 700 mm and length 520 mm mounted on horizontal axis enabling it to be rotated; an abrasive charge consisting of cast iron spherical balls of 48 mm diameters and weight 340–445 g is placed in the cylinder along with the aggregates.

$$\text{Abrasion value test } (\%) = 9.72 < 30 \text{ (satisfy)}$$

2.6 Flakiness Index

Flakiness Index is the percentage by weight of particles in it, whose least dimension (i.e., thickness) is less than three-fifths of its mean dimension.

$$\text{Flakiness index }(\%) = 10.81 < 35 \text{ (satisfy)}$$

2.7 Elongation Index

Elongation index is the percentage by weight of particles in it, whose largest dimension (i.e., length) is greater than one- and four-fifths times its mean dimension.

$$\text{Elongation index }(\%) = 23.59 < 30 \text{ (satisfy)}$$

3 Results and Discussion

3.1 Compaction Test

Figure 1 shows the plot between percentages of fibers verses optimum moisture content. Figure 2 shows the plot between percentages of fibers verses maximum dry density. It shows as the percentages of plastic chips increase, optimum moisture content and maximum dry density decrease.

Fig. 1 Materials (soil and plastic)

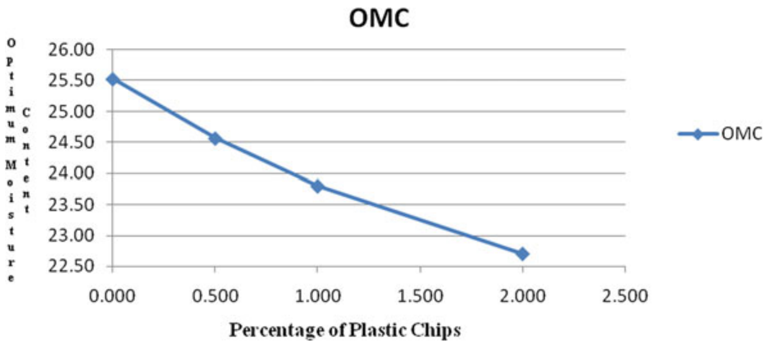

Fig. 2 Percentage of plastic chips verses optimum moisture content

3.2 California Bearing Ratio (CBR) Test

Figure 3 shows plot between bearing pressure verses settlement. In 1% of fibers, the CBR value increases and after that suddenly CBR value decreases. It shows that plastic strips are effective in some proportion. Figure 5 is the plot between pressure and settlement of soil aggregate system, which also shows the same response (Fig. 4).

Figure 6 shows that the comparison of CBR value between soil and soil aggregates system. In both the cases, the percentage of plastic waste is effective at 1 after that there is decrease in CBR value. The difference in increase of CBR value is almost in same rate for both the systemsQuery.

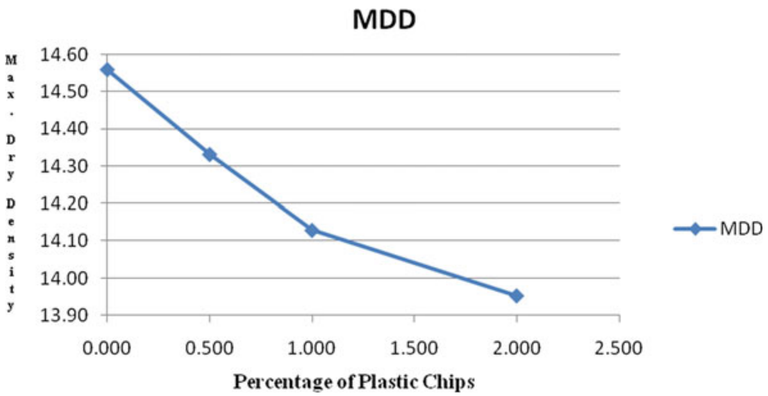

Fig. 3 Percentage of plastic chips verse maximum dry density

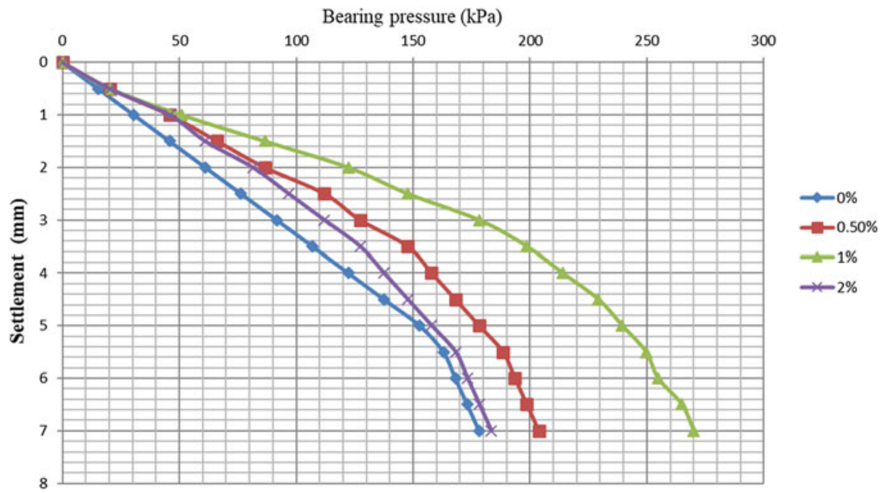

Fig. 4 Pressure verses settlement plot of soil system

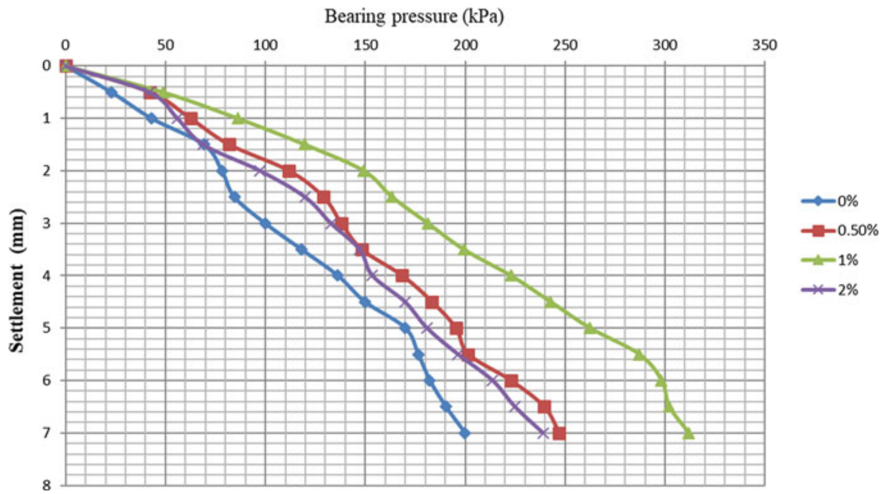

Fig. 5 Pressure verses settlement plot of soil aggregate system

4 Conclusions

From the California Bearing Ratio result, it has been concluded:

- By first observation it conclude that the value of CBR increases while plastic strips percentage increases.
- 1% of plastic fiber gives the optimum result in soil and soil aggregate system.
- After 1%, there is sudden decrease in CBR value again in both systems.

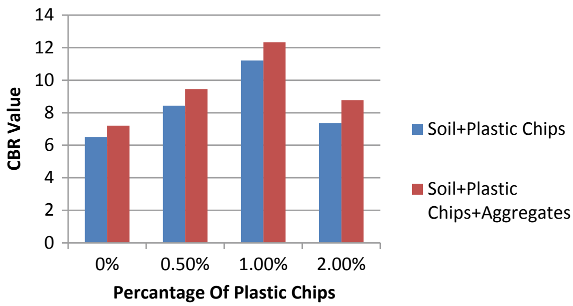

Fig. 6 Comparison of soil and soil aggregates system

- Soil and soil aggregate system shows the same response under loading because it provides good strength.
- So this type of technique can be used for embankment and pavement which may lead to solve problem of plastic waste management.

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