REUSE OF PLASTIC WASTE FOR ENHANCING THE STRENGTH PROPERTIES OF SOILS AN EXPERIMENTAL INVESTIGATION

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ABSTRACT: In these days geotechnical engineers often encounter weak subsoil, down to an appreciable depth, in respect of low to medium foundation load in and around a main city in India. This happens due to rapid urbanisation, which leads to exhaust the lands for construction. Thus there arises the need for use of reclaimed lands covering filled up areas developed for construction purposes. This necessitates ground improvement since the earlier low lying areas, which have been developed, were either marshy lands or agricultural ones. This is because shallow foundation with ground improvement may be cost effective in comparison to deep foundation. Recycling plastic waste for the purposes of construction is one of the major challenges in the world at present. PET (polyethylene terephthalate) strips obtained from drinking water bottle wastes may be used as an admixture of soil to improve its strength characteristics, and the mix may be used for filling of reclaimed land for ground improvement. With this in view, the present research work has been carried out with one type of locally collected clayey soil and two types of amended soil (clayey soil with 10% sand and 20% sand separately). These soils have been reinforced with randomly mixed PET bottle strips of different values of aspect ratio (length/width) of 1, 2 and 3 with constant width of 5 mm. For each aspect ratio the strips were mixed with 0.5%, 1%, 1.5% and 2% by weight of soil.

INTRODUCTION

Despite the ban in some Indian states, the use of plastic products, such as polythene bags, bottles, containers, and packaging strips, is increasing by leaps and bounds. As a result, open waste dumps are continuously filling up with this valuable resource. In many areas waste plastic is collected for recycling and reuses. The bottled water is fastest growing beverage industry in the world. Recycling plastic wastes formed due to use of water bottles has become one of the challenges worldwide. Plastic bottle recycling has not kept pace with the increase in virgin resin polyethylene terephthalate (PET) sales and the reuse becomes necessary for maintaining ecological balance. The best way to handle the increasing pressure of waste plastic on open dumps is to utilize it for ground improvement particularly for reclaimed land, after shredding with desired values of the aspect ratio (length to width ratio) and strip content. Moreover an environmental concern is also included by utilization of waste plastic materials and they can be made useful for improving the soil characteristics and to solve problems related to the disposal of waste plastic material.

The techniques employed to improve the properties of soil in respect of strength and other relevant characteristics of soil can be put into the following categories.

A. Soil stabilization by binding agent: It is the process of improving the engineering properties of soil by mixing some binding agent thus binding the soil particles like lime and cement.

B. Soil stabilization with reinforcement in the form of continuous planer members/sheets: Soils are strong in compression but weak in tension. This weak property of soil is improved by introducing reinforcing elements in the direction of tensile stress. Reinforcement material generally consists of galvanized or stainless steel strips, bars, grids, or fabrics of specified material, or wood polymer and plastic etc. the reinforcement is placed or layered at specific direction and position, more or less the same way as steel in concrete.

C. Soil stabilization with randomly mixed fibres/discrete members called ply soil: Soil stabilization with randomly mixed fibres/discrete members called ply soil: Randomly distributed fibres in soil (RDFS) are among the latest technique in which fibres of desired type and quantity are added in the soil, mixed and laid. The composite material is called 'ply soil'. Thus the method of preparation of RDFS is similar to conventional stabilization techniques.

METHODOLOGY

In order to study the effect of ground improvement with use of PET bottle strips three types of soil have been used in the present study. To produce two more types of soil in addition to the primarily collected clayey soil itself the soil has been mixed with 10% and 20% sand. Different mixes have been obtained for those three types of soil by mixing them with different percent of PET bottle strips having different aspect ratios. Thus three types of materials, namely, soil, sand and PET bottle strips have been used in this study. They have been depicted in details in respect of their characterization and properties in the following sections.

Primary Clayey Soil

The clayey soil has been collected from some location KLU University,Hyderabad, India.

Sand

In this study, all experimental works have been undertaken with one type of locally collected sand. The sand is medium grained uniform quarry sand having sub-angular particles of weathered quartzite.

Soil Types Used

For the current investigation collected clayey soil and two types of amended soil (with sand) have been used in this present study. The three types of soil namely S1, S2 and S3 have been identified as follows:

1) Clayey soil (S1).

2) Soil with 90% clayey soil and 10% sand by weight of dry soil (S2).

3) Soil with 80% clayey soil and 20% sand by weight of dry soil (S3).

PET Bottle Strips as Reinforcement

For the present study, plastic strips have been obtained from PET bottles, procured for this purpose. Strips of required sizes of 5 mm × 5 mm, 5 mm × 10 mm and 5 mm × 15 mm with aspect ratios of 1, 2 and 3 have been prepared by cutting the PET bottles. These strips have been used as reinforcement. The content of PET bottle strips has been varied with 0.5%, 1.0%, 1.5% and 2.0% to study the effect of the variation of content with different proportion of the soil-reinforcement mixes.

TEST PROCEDURES

Procedures of tests for determining engineering properties of different types of soil, PET bottle strips and soil-PET bottle strip mixes have been described in this section.

The three types of soil namely Clayey soil (S1), Soil with 90% clayey soil and 10% sand by weight of dry soil (S2) and Soil with 80% clayey soil and 20% sand by weight of dry soil (S3) without PET bottle strips has been tested. In this relevance procedure of Atterberg's limit, grain size distribution, standard Proctor compaction test, unconfined compressive strength test, and triaxial test (UU) have been described in this section. For locally available sand, particle size analysis by sieving method and for determination of tensile strength, density and water absorption of PET bottle strips a brief procedure has been depicted in this section. In case of soil samples mixed with plastic strip of aspect ratios of 1, 2 and 3 procedures of standard Proctor test, unconfined compressive strength test and triaxial tests have been followed appropriately. Consolidation test was carried out on soil-PET bottle strip mixes have been performed after obtaining optimum percentage of plastic strip content to observe the change in compressibility behaviour of soil due to addition of strips of PET bottles.

Tests on Soil Samples

In order to determine the properties of clayey soil and sand amended clayey soils with PET bottle strips an attempt has been made to carry out various relevant tests for determination of their different properties. The procedures of these tests are described in the following sections.

Atterberg's Limit

Casagrande liquid limit device is used to determine the Liquid limit and plastic limit of the soil as per IS-2720 (Part 5).

The liquid limit of fine-grained soil is the water content at which soil behaves practically like a liquid but has small shear strength. Its flow closes the groove in just 25 blows in Casagrande liquid limit device and the corresponding water content is considered as liquid limit.

The plastic limit of fine-grained soil is the water content of the soil below which it ceases to be plastic. It begins to crumble when rolled into threads of 3 mm diameter and the corresponding water content is taken as the plastic limit.

Grain Size Distribution

Grain size distribution of the soil is to be determined by standard hydrometer method using a hydrometer confirming to IS-2720 (Part 4). This method is applicable, if less than appreciable percent of the material passes 75 micron IS sieve. A 100 ml soil suspension is prepared in a measuring cylinder with 50 g of dry soil and 5 g deflocculating agent (Sodium hexameta phosphate). The hydrometer reading is taken at 0 min, un1/4 min, ½ min, 1 min, 2 min, 4 min, 8 min, 15 min, 30 min, 60 min and 24 hour from the start of the test. The hydrometer reading is then corrected for meniscus correction, dispensing agent correction and temperature correction. Immersion correction is considered from 2 min, with the help of calibration curve of the hydrometer to find the depth of centre of hydrometer. The particle size settling at the level of centre of hydrometer and the corresponding percent finer has been determined. The grain size distribution curve has then been plotted.

Standard Proctor Test

This Indian Standard code IS-2720 (Part 7) lays down the method for the determination of the relation between the water content and the dry density of soils using light compaction. In this test a 2.6 kg rammer falling through a height of 310 mm is used. The soil is uniformly mixed with requisite quantity of water. Then it is subjected to light compaction in proctor method. The soil is compacted in three layers applying 25 blows of hammer on each layer. The actual water content and dry density is then determined. The maximum dry densities and optimum moisture content of the unreinforced and reinforced soils are determined by standard proctor compaction. About 3 kg of dry soil passing through 20 mm IS sieve is taken. For compaction of soil-fibre mix, the required amount of fibre has been mixed with the dry soil before adding water. The test has been repeated for different water contents to find the optimum moisture content and maximum dry density.

Unconfined Compressive Strength Test

This Indian Standard code, IS-2720 (Part 10) describes the method for determining the unconfined compressive strength of clayey soil, undisturbed, remoulded or compacted, using controlled rate of strain. It is the load per unit area at which an unconfined cylindrical specimen of soil will fail in the axial compression test. Unconfined compression tests are carried out on cylindrical specimens of 38 mm diameter and 76 mm height. These specimens have been prepared at maximum dry unit weight and optimum moisture content state, with standard compaction. Initially all of the soil and half of the water and fibres are mixed, after which the proportions of water and fibre are gradually increased up to optimal water content and the required fibre percentage. The mix has been compacted in Proctor mould with desired water content and density. Then specimens have been extracted from the mould for carrying out unconfined compressive strength test. Stress-strain curves have been drawn and ultimate compressive strength has been determined for reinforced and unreinforced soil.

Triaxial Test (UU)

IS-2720 (Part 11) describes the test for the determination of the shear strength parameters of a specimen of saturated cohesive soil in the triaxial compression apparatus under conditions in which the cell pressure is maintained constant and there is no change in the total water content of the specimen. Unconsolidated undrained triaxial tests have been conducted on unreinforced and reinforced soil samples at the fibre contents and the aspect ratios. This test is limited to specimens in the form of right cylinders of nominal diameter 38 mm and of height 76 mm, twice the nominal diameter. The cylindrical specimens are prepared in a way similar to that explained earlier in unconfined compression tests. The tests have been conducted at three different confining pressures of 50 kPa, 100 kPa and 150 kPa. The stress-strain behaviour has been studied for both reinforced and unreinforced soils.

Consolidation Test

This test was performed as per IS 2720 (Part 15) to determine the coefficient of volume change that a laterally confined soil specimen undergoes when subjected to different vertical pressures. From the measured data, the e vs. log p curve has been plotted. These data are useful in determining the coefficient of volume change and the pre-consolidation pressure of the soil. In addition, the data obtained have been used to determine the coefficient of consolidation of the soil. The soil sample has been kept inside oedometer ring, with a porous stone and filling paper at the top and another porous stone and filter paper at the bottom. The load on the sample was applied through a lever arm, and the compression of the specimen was measured by a micrometer dial gauge. The load intensity has been doubled every 24 hours. The specimen has been kept saturated with water throughout the test. Consolidation tests have been run in floating ring type oedometer under standard load increment ratio starting from 0.25 kg/cm2 and going up to 8 kg/ cm2 as is generally done.

Tests on Sand

The test procedure of grain size analysis of locally available sand has been described in this section.

Grain Size Analysis

The grain size analysis for sand was performed in accordance IS 2720 (Part 4) with recommended sieve sizes. An oven dried sample of soil retaining on 75 □m sieve was testedwith sieve sizes of IS 4.75 mm, 2 mm, 1 mm, 600 □m, 425 □m, 212 □m, 150 □m and 75 □m. Sieving was performed by arranging those sieves one over the other in order of mesh opening with largest aperture sieve on top and smallest one at the bottom. A pan is kept at the bottom and a cover is fixed at the top. The sand sample is put in the top sieve and the whole assembly was fitted on a sieve shaking machine. The assembly was shaken for 10 minutes. The portion of soil sample retained on each sieve was weighed to determine cumulative percentage retained and corresponding percentage finer in order to draw grain size distribution curve.

Test on PET Bottle Strips

In order to determine the properties of PET bottle strips different relevant tests for determination of its tensile strength, density and water absorption have been carried out.

Average Thickness

Thickness of PET bottle strips was measured by micrometer with least count of Vernier scale of 0.01 mm. In order to find the average thickness ten samples were tested. The variation ranged between + 0.02 mm.

Tensile Strength

ASTM D638 describes the test method covers the determination of the tensile properties of plastics in the form of standard dumbbell-shaped test specimens when tested under defined conditions of pre-treatment, temperature, humidity, and testing machine speed. This test method can be used for testing materials of any thickness up to 14 mm. Tensile strength of PET bottle strip has been obtained by testing according to the method given in ASTM D638.

Density

ASTM D792 describes the method of determination of the specific gravity (relative density) and density of solid plastics in forms such as sheets, rods, tubes or moulded items. The density of PET bottle strip has been obtained following the method given in ASTM D792.

Water Absorption

In this test the plastic strips were immersed into the water for 24 hours for examining the water absorption capacity of the PET bottle strips. In this way, the water absorption of PET bottle strips was determined with respect to its dry weight.

RESULTS AND DISCUSSION

It is observed that OMC decreases and MDD increases with increase of percentage of sand. Sand can retain less moisture and the density of the sand is quite higher than that of clay. Angle of internal friction (ϕ) increases with increase of percentage of plastic strips but up to 1% of plastic strips. It is obvious since qualitatively increase of shear strength occurs with increase of density of a soil. Shear strength (c) and angle of internal friction (ϕ) increases with increase of percentage of sand. Since the density of the sand is quite higher than that of clay and sand helps to increase the angle of shearing resistance of the soil. OMC decreases and MDD increases with increase of percentage of plastic strips up to 1% and it is also noticed that beyond 1% of plastic strips the OMC increases and MDD decreases because plastic fibers have no water absorption capacity and also addition of plastic fiber increases the MDD. After addition of more than 1% plastic fiber there is increase of void ratio due to separation of soil grains caused by plastic fibers. After addition of 1% of plastic strips, angle of internal friction decreases for aspect ratio 1, 2 and 3. There is an increase in MDD, UCS, modulus of elasticity and shear strength with addition of plastic strips up to 1% beyond which these properties do not show any improvement of soil in respect of strength. Further this occurs up to aspect ratio of 3. The values of co-efficient of consolidation have been obtained from time-settlement data (not presented). The c_v values have also been furnished in tables.. The c_v values give an idea about the time required for settlement of a footing for occurrence of a particular degree of consolidation. The values for each soil type S1, S2 and S3 obey with reinforcement with different aspect ratios and optimum strip content of 1% have presented in the following sections.

Influence of strip content on properties of Soil-PET bottle strip mixes

In an attempt to find variation of plastic strip contents on properties of the mixes it is found necessary at this stage to find the optimum content of PET bottle strips at which the strength properties yield maximum value for each type of soil - S1, S2 and S3.

Therefore the variation of unconfined compressive strength test and also the Shear Strength parameters have been studied with variation of percent of plastic strips in the following sections.

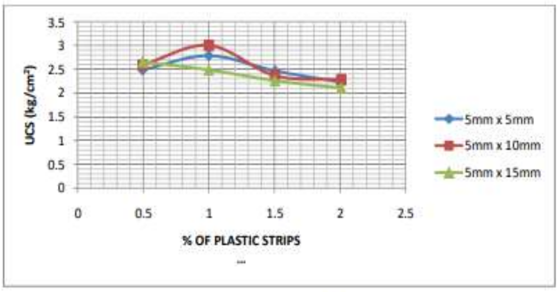
Variation of UCS with % of Plastic Strips

Variation of UCS with % of plastic strips for three types of soil has been presented in Fig.3.125 (a) to (c) for soil S1, S2 and S3 respectively. It is observed that UCS increases with increase of percentage of plastic strips but up to 1% and it is also noticed that after 1% of plastic strips the UCS decreases for aspect ratio of 1 and 2. In case of aspect ratio 3, there is a reduction of UCS. Optimum value comes at aspect ratio 2. It may also be found in Table 3.6 that up to aspect ratio 2 MDD increases for addition of 1% plastic fibre and beyond this aspect ratio and percentage of strip MDD decreases. The same trend is observed in case of UCS also due to the fact that increase of MDD causes increase of shear strength and thereby increase of UCS and the vice versa. Beyond AR of 2 and after addition of 1% plastic fibre UCS decreases for the same reason.

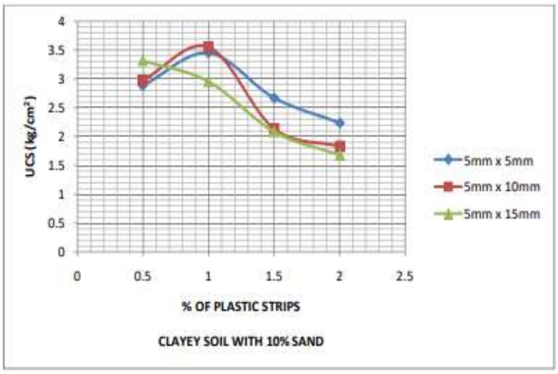
Variation of Shear Strength Parameters with % of Plastic Strips

Both the shear strength parameters C and ϕ have been considered to study the alteration of shear strength of soil due to addition of PET bottle strips.

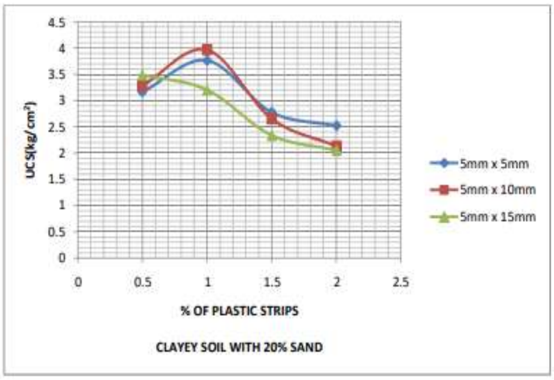
Variation of C with % of plastic strips has been presented in Fig. Similarly variation of ϕ with % of plastic strips has been shown in Fig. It is observed that shear strength (c) increases with increase of percentage of plastic strips but up to 1%. But beyond addition of 1% of plastic fibre, c decreases for aspect ratio 1 and 2. For aspect ratio 3, there is reduction in value of c. Angle of internal friction (ϕ) increases with increase of percentage of plastic strips but up to 1% of plastic strips. After addition of 1% of plastic strips, angle of internal friction decreases for aspect ratio 1, 2 and 3. Optimum value occurs at aspect ratio of 2 for shear strength. At aspect ratio of 3, ϕ increases up to 1% of plastic strip but since there is an appreciable reduction in c, effectively the shear strength is reducing. Hence optimum value occurs at aspect ratio.



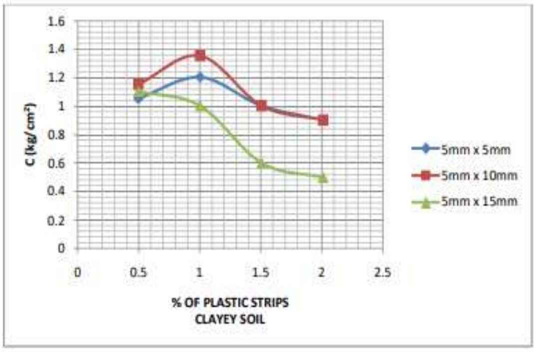
UCS vs. Percentage of plastic strips – Soil S1



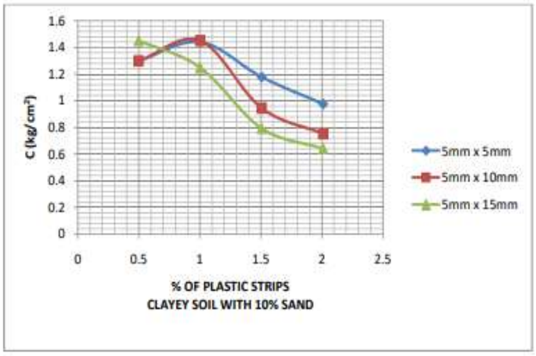
UCS vs. Percentage of plastic strips - Soil S2



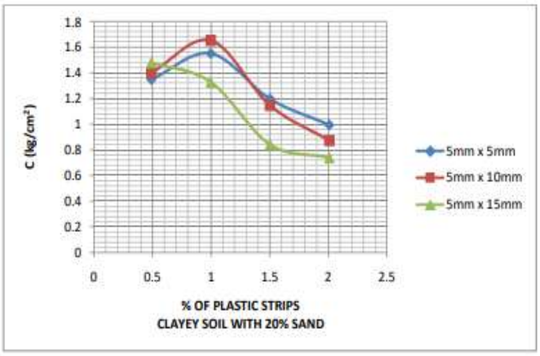
UCS vs. Percentage of plastic strips - Soil S3



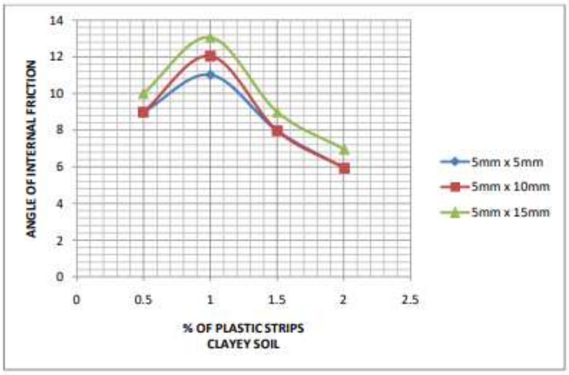
C vs. Percentage of plastic strips



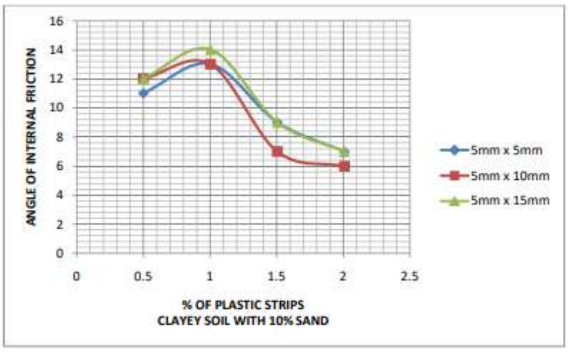
C vs. Percentage of plastic strips



C vs. Percentage of plastic strips



Angle of internal friction vs. Percentage of plastic strips



Angle of internal friction vs. Percentage of plastic strips

SUMMARY AND CONCLUSIONS

Scarcity of land with appreciable bearing capacity for construction of structures is increasing day by day with progress of civilization and industrialization. At the same time there are many waste materials deposited due to human activities all over the world. Such a waste is PET bottle used and thrown away by people as waste. Recycling of this may reduce environmental hazard as well as help in construction on weak ground. It further appears that there is scope of study on behaviour of clay mixed with randomly distributed plastic fibre obtained from waste PET bottles lies in recycling of plastic waste to reduce environmental hazard. Mixing of waste plastic strips with soil may therefore be done to increase the strength and stability of soil.

With this in view the present study has been carried out with a locally available clayey soil. This has been mixed with 10% and 20% sand to make two more types of amended soils. Thus three types of soils have been obtained as follows:

a) Original soil S1,

b) S2 (Soil+10% sand) and

c) S3 (soil+20% sand).

Further PET bottles have been procured and they have been cut into pieces of 5mm width with aspect ratio of 1, 2 and 3. For each aspect ratio four strip contents, 0.5%, 1%, 1.5% and 2% have been mixed with each type of soil.

So, there are 3 soil types and for each soil type there are 3 (soil types) x 3 (aspect ratio) x4 (fibre content) = 3 soils + 3 x 3 x 4 (=36) mixes. Different tests, such as, grain size analysis and Atterberg's limits have been done for characterization. Unconfined compressive strength and UU triaxial tests have been done to obtain strength of these three types of soil and 36 mixes at optimum moisture content obtained earlier with the help of standard Proctor test.

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