CHARACTERIZATION OF STRENGTH AND STIFFNESS PARAMETERS OF CLAYEY SOIL PARTIALLY REPLACED WITH PLASTIC GRANULES

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ABSTRACT: Plastics contribute a major portion of the waste generated by human civilization. As these materials are non-biodegradable, they have a considerable life and huge potential in providing solutions to complex engineering problems. In geotechnical engineering applications, researchers are motivated to use plastic wastes either as an alternative to or as a partial replacement of the conventional materials. In the present study, recycled plastic granules that are available as a raw material to plastic industries are utilized to investigate their role in influencing the shear strength and stiffness parameters of the clayey soil. Unconsolidated Undrained (UU) Tri-axial tests are performed on various samples of clayey soil that are partially replaced with recycled plastic granules at different percentages (2.5%, 5%, 7.5%, 10%, 12.5%, and, 15%) by the dry weight of soil. Through experimentation, it is established that optimal addition (7.5%) of plastic granules in clayey soil is advantageous in terms of improving the strength and stiffness of the plastic granules mixed clayey soil.

INTRODUCTION

Geotechnical engineering problems, such as, bearing capacity of shallow footing, stability of slopes or embankments, etc., are dependent upon the shear strength parameters of the soil, i.e., cohesion and angle of internal friction; thus, the improvement in shear strength of soil requires improvement in these parameters. Researchers suggest different approaches and techniques for improving the engineering properties of soil through various ground improvement methods, such as, removal and replacement, pre-compression, vertical drains, in situ densification, grouting, stabilization using admixtures, reinforcement, etc. A detailed discussion on various ground improvement techniques is available in [1, 2, 3].

In recent years, researchers have also investigated the potential use of plastic waste [4, 5], rubber tyre waste [6], natural or synthetic coir fibers [7] as well as geosynthetics [8] in geotechnical engineering applications and provided many useful practical and sustainable solutions to various geotechnical engineering problems. In particular, while utilizing natural or synthetic coir fibres, researchers have reported and discussed the altered values of the shear strength parameters with % addition of the fiber content. Maher and Gray [9], Mahmoud [10] reported linear increase in the angle of internal friction value with percentage of fiber content added to the soil. Other researchers [11, 12] working with silt clay showed that only cohesion depends on the fiber content. Along these lines of thought, authors of the present study have made an attempt to use plastic granules in improving the engineering properties of clayey soil and the objective of the present work to investigate the potential use of plastic granules in optimally improving the strength and stiffness characteristic of plastic granules mixed clayey soil through a series of unconsolidated undrained (UU) tri-axial tests.

For the purpose of performing unconsolidated undrained tri-axial tests, 425 μm passing Indian standard sieve clayey soil was mixed with recycled plastic granules (at varying percentages by the weight of dry soil) and was compacted on the wet-side of OMC, i.e., 15% with a target bulk density of 1.80 g/cc (dry density = 1.565 g/cc). These tests were performed to evaluate the response of plastic granule reinforced soil in terms of stiffness and shear strength or ultimate behaviour. These characteristics were quantified by measuring the elastic modulus and shear strength parameters of the different soil – plastic granules mix from the stress – strain curves obtained and it is shown that an optimal % mix of plastic granules with the clayey soil optimally improve the strength and stiffness of plastic granules mixed clayey soil.

EXPERIMENTAL PROGRAM

Planning of experiments

Experimental planning was done with the target of evaluating the relevant soil mix properties, starting with minimal percentage of plastic granules in the soil and increasing it till the percentage of plastic granules in the mix would range so high that the samples formed would turn out to be of poor quality. The tests were conducted at different plastic granule mix percentages by the weight of dry soil as 2.5%, 5.0%, 7.5%, 10%, 12.5% and 15%. For each soil mix, 3 unconsolidated undrained tri-axial tests were performed at different cell pressures of 50kPa, 100kPa and 150kPa each and average response (or average of two similar responses) is reported for each case. It was observed that the samples cast at 15% plastic granule mix turned out to be of poor quality and thus the scope of the work analysis was restricted to 15% mix. The analysis of the findings was done by stress-strain plotting of the results and observing the corresponding ultimate strength and elastic modulus of the specimens for different cases.
Materials

The clayey soil used in the present study was sampled from the region of Madhya Pradesh, in central India and the properties of the same are obtained as: Liquid Limit = 35%, Plastic Limit = 21%, Shrinkage Limit = 16%, Maximum Dry density = 1.85 g/cc, and OMC = 12%. The particle size distribution curve of the clayey soil (passing 425 micron sieve size) is presented in Figure 1. As per Indian standard soil classification system, the clay soil is classified as CL – CI (clay with low to intermediate plasticity). The clayey soil is mixed with plastic granules as shown in Figure 2.

The Plastic granules used in the present study were obtained from a mini plastic recycling plant in Mumbai, Maharashtra and are classified as LDPE (Low density Polyethylene). The size of these granules is 2.36 mm passing and 1.18 mm retaining on Indian standard sieve. The average size of a cylindrical granule is 1.8 mm in diameter and 3 mm in length. LDPE granules have a density of 0.917 – 0.94 g/cc. They possess low hardness and stiffness but high resistance to water, moisture, organic solvents and chemicals.

The plastic granules are manufactured after recycling of plastic waste in a five step process, i.e., (i) Waste plastic collection; (ii) Manual sorting; (iii) Chipping; (iv) Washing; and (v) Pelleting. The pelleting is done by melting the chips and extruding them out first through a fine grill to remove any solid dirt or metal particles that have made it through the treatment thus far and then through a die of small holes. If the plastic was simply allowed to extrude from these holes it would come out as spaghetti-like strings and quickly tangle together. However, it is sprayed with water as it comes out (to prevent the plastic from sticking together) and cut off by rotating knives to give small, cylindrical pellets. Figure 3 shows the plastic extruding granulation unit commercially available in the market.

![Fig. 3 Typical plastic extruding granulation unit that is available in market](image)

Specimen preparation and testing procedure

Clayey soil passing the 425 micron Indian standard sieve was mixed with the plastic granules (2.36mm-1.18mm) weighed at a certain percentage (say, 5%) by the weight of dry soil. A water content of 15%, by the weight of dry soil, was then added to the dry mix to prepare it on the wet-side of OMC (optimum moisture content).

![Fig. 4 Density - moisture content tests results (IS light compaction) for clayey soil alone and clayey soil mixed with plastic granules](image)

The information on maximum dry density and optimum moisture content for the clayey soil alone as well as for clayey soil with different percentage of plastic granules mix were obtained by conducting Indian standard light compaction test [13] equivalent of the standard proctor test.
Fig. 5 Comparison of stress strain plot from UU test obtained for clayey soil alone as well as for clayey soil mixed with different % of plastic granules.
The volume of the mould is 1000 cc, the weight of hammer 2.6 kg and the drop 310 mm. The soil is compacted in 3 layers; each layer is tamped 25 times. From the compaction curves obtained for all the cases, it can be noted that there is not much difference between maximum dry density and OMC values (Figure 4). The soil mix was then compacted in a mould of 1000 cm³ capacity to achieve a targeted bulk density of 1.80 g/cc. All the tri-axial specimens (clayey soil alone as well as for clayey soil with different percentage of plastic granules mix) were prepared at a fixed bulk density (1.80 g/cc) and moisture content (15%) values to ensure uniformity. The mould containing the compacted moist soil was then placed in a sample extractor and the tri-axial moulds were placed in position to extract the samples. Finally, the cylindrical samples were trimmed and prepared with a diameter of 38mm and length of 76mm. UU tri-axial tests were then conducted on the prepared samples, compliant with the Bureau of Indian Standard code [14].

Results of Experimentation

Figure 5 provides a comparison of the strain - stress plots of clayey soil with no mixing and different % mixing of plastic granules at cell pressures of 50kPa, 100kPa and 150kPa, respectively. These stress–strain plots provided values for elastic modulus (initial modulus, Eᵢ) as well as ultimate strength (deviatoric) of the clayey soil with no-mix as well as clay–plastic granules mix, at different confining pressure values as summarized in Table 1.

Table 1: Initial tangent modulus (Eᵢ) and ultimate strength (σᵢₚ) for clay soil – plastic granules mixed at different confining pressures

<table>
<thead>
<tr>
<th>% Plastic Gran. mix</th>
<th>Initial Modulus (Eᵢ), MPa</th>
<th>Avg Eᵢ, MPa</th>
<th>Ultimate strength (σᵢₚ), kPa</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>50</td>
<td>100</td>
<td>150</td>
</tr>
<tr>
<td>0</td>
<td>3.10</td>
<td>5.10</td>
<td>5.80</td>
</tr>
<tr>
<td>2.5</td>
<td>3.26</td>
<td>3.29</td>
<td>4.94</td>
</tr>
<tr>
<td>5.0</td>
<td>2.36</td>
<td>4.53</td>
<td>4.50</td>
</tr>
<tr>
<td>7.5</td>
<td>3.52</td>
<td>4.53</td>
<td>7.07</td>
</tr>
<tr>
<td>10.0</td>
<td>4.53</td>
<td>3.84</td>
<td>5.89</td>
</tr>
<tr>
<td>12.5</td>
<td>4.16</td>
<td>4.53</td>
<td>5.26</td>
</tr>
<tr>
<td>15.0</td>
<td>3.07</td>
<td>3.44</td>
<td>4.00</td>
</tr>
</tbody>
</table>

Form these results, it can be noted that the values of initial tangent modulus and ultimate strength of the clay soil mixed with plastic granules initially decreases with the addition of 2.5% of plastic granules and it increases till 7.5% plastic granules mix and then again starts decreasing with further addition of plastic granules. It can also be noted that the strength and stiffness parameters suddenly drops at 15% plastic granules mix, which may be due to the poor quality of the samples obtained. It is noted that 7.5% replacement of plastic granules optimally improves the strength and stiffness parameters of plastic granules mixed clayey soil.

Conclusions

The addition of plastic granules to clayey soil initially reduces the strength and stiffness parameters and then increases and at 7.5% of plastic granules mix an optimum values of these parameters are obtained. Further addition of plastic granules reduces the strength and stiffness of the plastic granules mixed clayey soil. The study clearly confirms the potential use of plastic granules in geotechnical engineering problems and shows that optimal replacement of plastic granules in clayey soils is 7.5%.

References