Stabilization of Clayey Soil Using Lime and Plastic Fiber in Sub Grades

Manish Chauhan, Sumit Kalra, Harpreet Singh

Abstract*: Soil is the basic and most commonly used material in civil engineering. Soil is used in building, highways, bricks, bridges; road rail tracks and is responsible for the stability of the structure. There are various kinds of soil available on earth; the soil is distinguished as per the material properties, size, composition, and various textures. The clay soil is a type of soil having a fine-grained natural rock that integrates one or more clay minerals with traces of metal oxides and organic matter. According to the composition of the material, the clay also has a variety of features. It is slow, fast, and difficult to accelerate and is utilized for something with fine particle size. In this research, soil stabilization is carried out to achieve the engineering properties of soil for subgrades construction. Waste plastic bottles are used in the construction of subgrade to reduce the landfill and utilize raw waste material in reinforcing the soil. Therefore, we have tried to stabilize the clay soil with the different percentages of quick lime (2%, 4%, 5%, 6%, 8%, 10%, 12%). The tests such as Maximum Dry density (MDD), California Bearing Ratio (CBR) at various percentages of plastic strips have been performed to determine the strength of the clay soil. Also, the swelling index of clay soil and the microscopic test is also performed to analyze the change in the engineering properties of soil.

***Index Terms*: Clay soil, Lime, Plastic material.**

I. INTRODUCTION

The soil in nature is very useful for agricultural and engineering point of view. From an engineering perspective, soil plays a different role in buildings, roads, railways, airports, and other buildings [1]. The strength of the structure depends upon the type of soil, if the soil has low strength for a particular structure on site, stabilization techniques are needed to increase the strength of the soil [2]. Therefore, before applying soil around the foundation, an engineer must know about its properties as well as the factors affecting their behaviours. Soil stabilization is crucial to ensure soil properties, as lime and plastic fibres provide stabilization of the soil to strengthen the cracking [3]. Adding lime and plastic fibre reduces the content of optimal water, increases strength and maximize dry density along with swelling potential minimization, fluid limit, and plasticity index [4]. But the excessive addition of sulphate content may increase the swelling in soil, reduce plasticity with brittle failure feature of soils. In this paper, the soil stabilization has been performed with the lime and plastic fibre that is obtained from the waste material.

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1.1 Index properties of clay soil

Index features are the soil characteristics that help to identify and classify the soil to fulfil general engineering purposes. The test is mainly conducted in the laboratory [6]. For the measurement of soil features, soil sample may be used. These properties include parameters like compressibility, permeability with shear strength. The test required to determine engineering features is complicated and takes a lot of time. Sometimes, geotechnical engineers are interested to make a rough assessment of properties instead of performing different tests. This is possible only if the index properties of the soil are determined.

II. RELATED WORK

Muntohar and A. S. (8, 2009) have used lime with rice husk ash for the stabilization of soil. The experiment has been performed in terms of compressive strength and tensile strength has been examined. The laboratory investigation results show that inclusion of the plastic waste fibre increased significantly both the unconfined compressive strength and tensile-split strength of the stabilized clay soil. The fibre length plays a significant contribution to increasing the soil strength. To contribute for any significant improvement on compression as well as tensile strength, the fibre length should be in the range of 20 mm to 40 mm. Fibre reinforcements also reduced soil brittleness by providing smaller loss of post-peak strength.Satyam Tiwari et al. (9, 2016) have used waste fibre for soil stabilization. The tests such as direct shear test and in confined compression tests have been conducted on two soil samples to determine the shear strength of unsaturated soil. The fibre has been added in various percentages 0, 0.05, 0.15, and 0.25. From the experiment, it has been determined that the specific gravity of soil by adding fibre in 005 per cent was increased by 003 %. Elias et al. (10, 2016) have investigated the effect on soil stabilization using human hair and compare the results with lime. Human hair has been added to the soil and a number of samples have been prepared. The tests such as UCC and strength analysis have been performed to determine the engineering characteristics of the soil. From the tests, it has been observed that when lime with human hair is added into the soil the strength of soil has been increased. Fauzi et al.

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(11, 2016) investigated the engineering characteristics of waste plastic “High-density polyethene” along with crushed glass that is integrated with clay soil. The CBR test has been performed on clay soil specimen that has been prepared with optimum water content. The content has been varied in different percentage4, 8 and 12. The electronic microscope test has also been performed. From the test, it has been analyzed that with the increase in the HPPE along with glass quantity the stability of soil has been increased.

Reddy et al. (12, 2018) have focused on determining the strength of soil by mixing plastic waste, ‘steel dust as well as wood waste in definite proportion. The study has been analyzed that the addition of 10 % of plastic material increases the compressive strength of approximately 2.2 times as compared to unsterilized soil. Also, the shear strength has been increased by 35 %.

III. MATERIALS AND METHODS

A number of materials are used during the stabilization of soil. The properties of these materials depend upon the place where these materials are found. The complete classification of these materials based on their important characteristics is useful for understanding soil response that is changed in stress levels and different environmental conditions. In addition, it is a detailed understanding of the material properties, which is very important for the development of appropriate stabilization methods. A brief description of used material such as soil, lime and plastic fibre is given below.

3.1 Soil

Soft soil is considered for the stabilization process. As the soft soil has a larger surface area compared to their particle diameters, it is easy to stabilize these fine-grained granular. The clay utilized in this research has a broad mineral composition [13]. This includes various types of clay minerals in various proportions, in particular, kaolinite, mixed layer clay and non-clay minerals, especially quartz, and/or organic and colloidal materials. Very small amounts of certain clay minerals can have a large effect on the physical properties of clay deposits [14].

Table 1 Physical properties of clay soil

Properties	Range
Specific Gravity	2-3.3
Hardness	<2.5
Refractive index	1.47-1.68
Sieve Analysis	86 % passing 75 micron sieve

3.2 Lime

Lime is a multifunctional mineral that can be available in different forms and find application in environmental, metallurgical, architectural and chemical/industrial [15]. The fastest growing lime is used in environmental applications where lime is used in compliance with air, drinking water, wastewater and solid waste regulations. The strength of the soil is increased by the cation exchange instead of pozzolanic reaction effect exit in cement. During the addition of lime in the soil, the clay particles convert natural clay particles as per the requirement such as interlocking metalline structure. Individual clay soil becomes drier and less vulnerable to water content [16].

3.3 Plastic

Plastic is a rich waste material on the earth's surface. These products are made by human and are harmful and non-biodegradable to the soil. Plastic bottles are constructed by high-density plastic. In this research, PET plastic has been used as a stabilizer in the substrate to enhance soil loading capacity. These strips are 20mm × 3mm (length × width). Waste plastic strips are used as a reinforcing material in the clay soil for the present experiment. The physical, as well as chemical characteristics of waste plastic strips, are listed in table 2.

Table 2 Physical & chemical characteristics of plastic strips

Exterior	Plastic Strips
Odour	Odorless to mid
Specific gravity	1.20 -1.55
Vapour Pressure	<0.1
pH	Not applicable

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Figure 1 Plastic Strips

3.4 Methodology

Initially, the soil sample is collected from the Chandigarh university campus. A sample is prepared by mixing the lime along with plastic with clay soil in different amount. In the current research, lime is mixed to clay soil in its natural water content. The quantity of lime is varied from 2%, 4%, 6%, 8%, 10%, 12 % and 5 %. Also, the plastic content is varied from 0.2 %, 0.4 %, 0.6%, 08%, 1% and 1.2 %. Before perform testing on soil following steps are conducted:

i. Initially, size distribution of soil has been done using sieve analysis process.

ii. The test such as plastic limit and liquid limit of soil has been determined in order to know the type of soil.

iii. Specific gravity test has been performed to determine the weight that is how much the substance is heavier than water.

iv. Standard protector test is performed to determine the maximum Dry density of soil (MDD)

4 Experiment Result

The index characteristics of the clay soil test results are illustrated in table 3. Changes in the MDD, unconfined shear test are depicted in the figure.

Table 3 Results

Liquid Limit of Soil	55%
Plastic Limit of soil	48%
Specific gravity test	2.76
MDD	1.62
Optimum Moisture content	21.5%
Free swell index	30%

4.1 Sieve Analysis

Sieve analysis test is used to determine the weighs and the particle size distribution of the textured material and the amount of material that is suspended by each sieve as part of the whole mass, allowing the material to be gradually smaller.

4.2 Determination of Liquid Limit of Soil

This test is carried out to find out the soil liquor limit in accordance with IS: 2720 (Part 5) - 1985. This test is used to find the liquid limit of soil in which the soil behaves like liquid with smaller shear strength. The number of blows utilized to contact the soil sample is noted. The graph is prepared by considering a number of blows towards abscissa and on the ordinates, water content has been taken. The fluid limit is expressed by $\mathbf{w_c}$.

4.3 Determination of Plastic Limit of soil

This test is made to study the plastic constraints of the soil I accordance with IS 2720 (Part 5) - 1985. It is the value below which the soil behaves like plastic and when rolled into 3 mm diameter yarns begin to collapse.

4.4 Specific gravity test

The specific weight of a substance indicates that the substance is heavier than water. Specific soil weight is determined in unstable soils and in different locations of strong soil.

4.5 Standard protector test

This test has been performed on version soil of 3 Kg. This test is used to determine the maximum Dry density of soil (MDD). It is obtained where the soil is compressed at relatively high humidity and approximately all the air is drawn is known as the optimum moisture content. The MDD can be achieved by plotting graph between the water content and dry density as abscissa and ordinate respectively. The graph and the values with lime are shown in the figure below.

Table 4 MDD for Lime

Lime Content (%)	MDD
2	1.60
4	1.62
5	1.64
6	1.65

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8	1.66
10	1.67
12	1.68

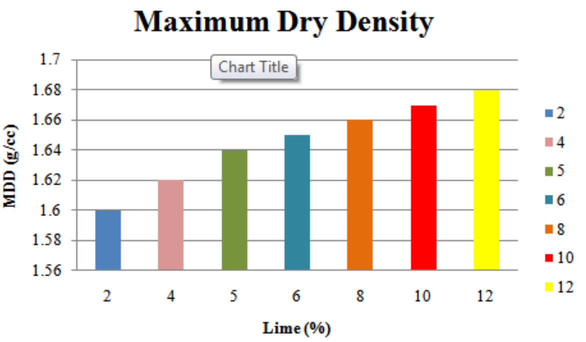

Figure 2 MDD w. r. t. Lime

Figure 2 represents the graphical representation of MDD measured with respect to lime content. From the above figure, it is determined that as the lime content increase the MDD also increases. The highest relative increase in MDD is obtained from 4 % to 6 % of lime content. Therefore we also perform a test on 5 % and obtained MDD of about 1.64. Therefore we consider 5 % lime to conduct a test in order to make structure economical.

Table 5 MDD for Plastic fibre

Plastic Strip Content (%)	MDD
0.2	1.70
0.4	1.71
0.6	1.72
0.8	1.73
1.0	1.71
1.2	1.70

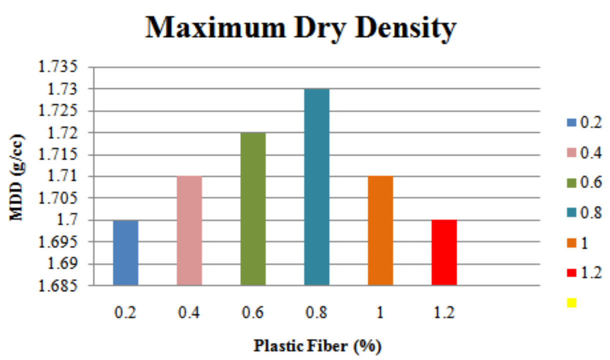

Figure 3 MDD w. r. t. Plastic Fiber

Also the MDD has been analyzed by mixing 5 % lime with plastic content in different ratio (0.2 %, 0.4%, 0.6%, 08%, 1% and 1.2 %). From the above figure, it is clear that MDD increases up to 0.8 % of polypropylene content after that it starts decreasing. Higher is the MDD higher is the strength of the soil.

4.6 California Bearing Ratio (CBR)

The CBR test is used to determine the soil resistance to the standard puncher's reputation in controlled density and humidity conditions. This test has been investigated by "the California division of Highway" and utilized for the classification and evaluation of soil and substrate materials for flexible pavements. The soil of 5 Kg has been considered to perform the CBR test. The reading has been conducted with lime and without soil only. For version soil and soil with lime, the quantity of soil of about 5 Kg has been considered. The values observed during the testing process are listed in the table below.

Table 6 CBR of clay soil with plastic at different percentage

Plastic Content (%)	CBR (%)
0.2	2.1
0.4	3.26
0.6	3.86
0.8	4.8
1.0	4.4
1.2	2.9

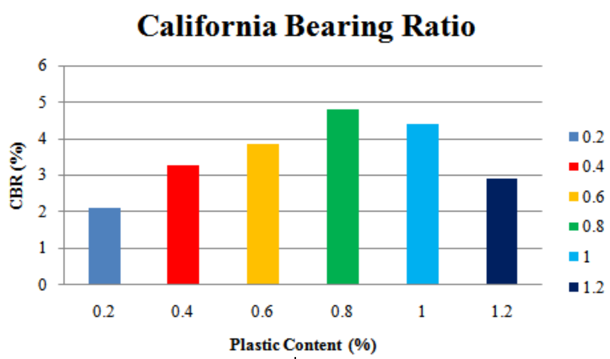

Figure 4 CBR with different plastic content

Table 7 CBR of clay soil with lime

Penetration (%)	CBR (%)
2	2.16
4	4.68
5	6.25
6	5.82
8	2.68
10	3.02
12	2.82

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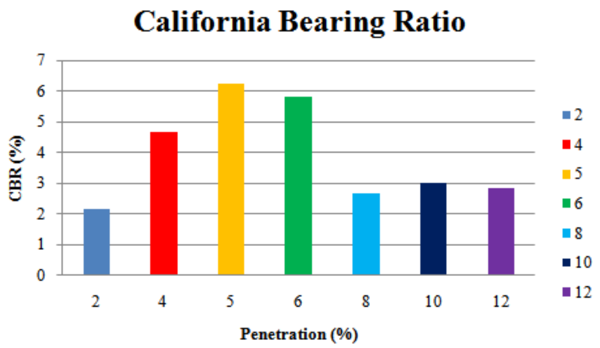

Figure 5 CBR of clay soil with lime

Table 8 CBR of clay soil with lime and plastic strip

Sample	Soaked CBR (72 hrs)	Unsoaked CBR (%)
Parent Soil (Clay Soil)	1.16	1.84
Clay soil +5 % lime	5.04	6.15
Clay soil +5 % lime +0.2% plastic	5.22	6.56
Clay soil +5 % lime +0.4% plastic	6.19	8.39
Clay soil +5 % lime +0.8% plastic	8.56	10.02
Clay soil +5 % lime +1.0% plastic	5.36	9.83
Clay soil +5 % lime +1.2% plastic	2.80	5.46

4.7 Unconfined compress Strength (UCS)

In practice, it is employed to determine the unconfined compressive strength of the prepared soil specimen. It is utilized to measure the consolidation, unstable cut-off strength of the soil. An untreated compressive force is compressive stress that is unsuccessful in the case of an unsightly cylinder soil sample under a simple pressure test. Pressure stress for each step is calculated by dividing the entire load within the accurate area. During this test, 5 % of lime is taken as constant material whereas the percentage of polypropylene has been varied to check the stability of clay soil using UCS. The values of UCS are listed in the table below.

Table 9 UCS

Plastic Fiber polypropylene (%)	UCS values (Kg/cm^2)
0.2	0.224
0.4	0.89
0.6	1.30
0.8	1.60
1.0	1.39
1.2	1.02

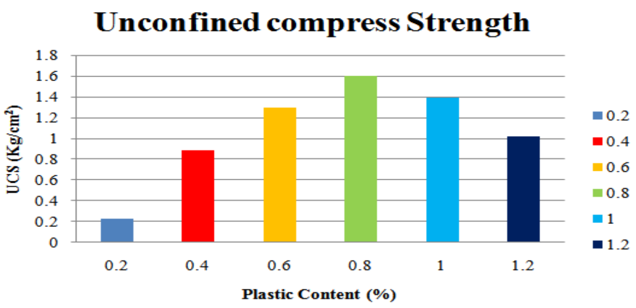

Figure 6 UCS with varied plastic content

The results examined from different polypropylene fibres while keeping lime (5%) as a constant is illustrated in Figure 6. From the graph, it is analyzed that as the Polypropylene fibre with constant lime (5%) increase the compression strength increased up to 0.8 % and after that, it starts decreasing with the further mixing of polypropylene content. The maximum UCS value observed at 0.8 % of Polypropylene fibre in the soil is 1.6 Kg/cm^2.

4.8 Microscopic test

The microstructure of soil without and with lime (5%) is shown in figure 7 and 8 respectively. Larger landowners can often be easily seen - but there are very few organisms in the soil that requires special equipment to visualize them. Such a device is known as a "Scanning Electron Microscope"(SEM). This machine is able to show the most accurate aspects of the soil in a breathtaking way.

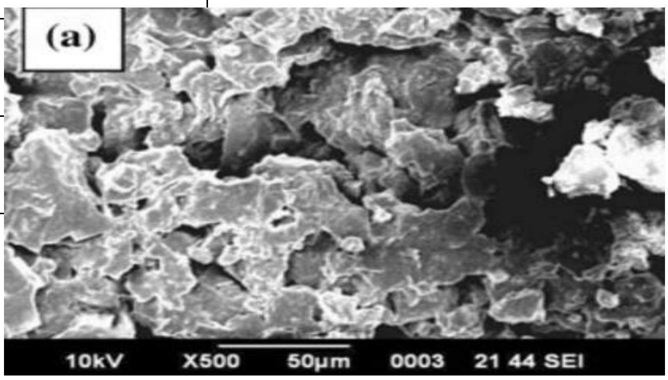

Figure 7 SEM images of soil

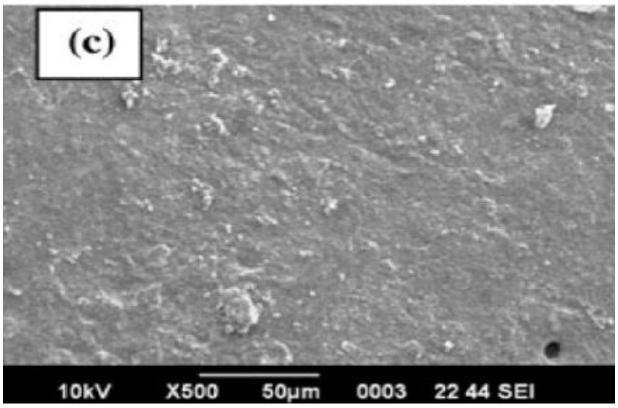

Figure 8 SEM images of soil +5% lime

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4.9 Free swell index

It is used to measure the enhanced volume of soil. It is determined using the equation written below.

$$\textbf{Free sweel index}\,(\%) = \frac{Vol_d - Vol_k}{Vol_k}$$

Vol_d → Signifies the volume of the soil sample which is read from the graduated cylinder comprises of distilled water.

Vol_k → Represents the volume of the soil sample read from the graduated cylinder that includes kerosene.

Then the test has been performed by adding Lime in different percentage. The free swell index is measured as per the IS code: 2720 part 40.

Table 10 Observation sheet

Determination number	Parent Soil	Soil +5% Lime
Mass of dry soil passing 425 µ (gm) sieve	10	10
Volume in water after 24 hrs swell Vol_d (cc)	14	13
Volume in kerosene after 24 hrs Vol_k (cc)	10	10
Average Free Swell Index	40%	30%

V Conclusion

From this research, we have analyzed that lime and waste plastic bottles can be used fruitfully to stabilize clay soil. The use of plastic products like polyethylene bags, water bottles, containers and food packaging is rising day by day. Removal of plastic wastes without causing environmental hazards has become a serious problem for this modern era. Thus, using plastic bottles as a soil stabilizer is economical and profitable. Therefore, this research contributes to reducing the amount of plastic waste generating useful material from non-useful waste materials that lead to the sustainable community of society. A number of tests have been carried out to determine the effects of randomly dispersed plastic wastes fibre reinforcement on the stabilized soil with constant lime (5%). Following points are observed after performing numerous experiments.

i. The optimum quantity of lime that can be added to clay soil to obtain the best result is 5 %. Using this quantity the structure is economical.

ii. The compressive strength increases up to 0.8 % of Polypropylene fibre and a percentage increase of 23.08 % has been obtained.

iii. The maximum value of Unsoaked CBR (10.02) and soaked CBR (8.56) is obtained at 0.8 % of Polypropylene fibre. Thus there is an increase of CBR about 17.06 % has been obtained at 0.8 % of plastic content.

iv. Free Swell index of parent soil is more compared to mixed soil.

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