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Soil Stabilization Using Chemically Induced Calcium Carbonate Precipitation and Urea

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Abstract: Soil stabilization is a critical technique in civil engineering to improve the engineering properties of soil, making it suitable for construction purposes. This abstract presents a novel approach to soil stabilization using waste lime and urea, aiming to enhance soil strength and reduce environmental impact. Waste lime, a byproduct of various industrial processes, and urea, a common agricultural fertilizer, are both readily available and cost-effective materials. When applied to soil, waste lime and urea react chemically to form stable compounds, reducing soil plasticity and increasing its load-bearing capacity. The Present Study investigates the effectiveness of stabilizer i.e. calcium carbonate precipitation (waste lime) and urea to increase the strength of soil subgrade. This study addresses the contemporary need for sustainable and eco-friendly soil improvement techniques in civil engineering projects. Waste lime and urea, recognized for their cost-effectiveness and minimal environmental impact, are employed as stabilizing agents to enhance soil properties. Laboratory experiments involve varying concentrations of lime and urea to analyse their impact on the soil's mechanical and chemical characteristics. The aim of the study is to improve soil cohesion, strength, and overall stability. For this, different tests were performed in the lab which is pH, compaction, liquid limit, plastic limit, Specific gravity, compaction tests, and Unconfined compression Test (UCS).

Keywords: Soil Stabilizer, agricultural Fertilizer, Unconfined Compression Test.

I. INTRODUCTION

Swelling soils are soils that swell when they get wet and shrink when they get dry. These soils cause serious damage, specially to the light structures such as roads, airports, garden walls, infrastructure, and single-storey buildings. A significant part of the damage caused by swelling soils can be avoided by detecting these soils in preliminary studies and taking appropriate cautions.

Soil stabilization is the process of improving and stabilizing the technical features of the soil. It's utilized to improve shear resistance and reduce unqualified soil qualities like permeability and consolidation. This technology is mostly used in the construction of highways and airports. Compaction and pre-consolidation are commonly employed to improve soils that are already in good condition. Soil stabilization, on the other hand, extends beyond increasing the usage of soft soil and minimizing the cost of soft soil renewal. Chemical modification of the soil material itself, in addition to studies on soil mass interaction, is an important part of this process. Ground stabilization is sometimes used to make inner city and suburban streets more permeable. UCS testing has limited utility in the realistic prediction of load–deformation responses because of the lack of control over the drainage condition other ability to examine the impact of confining pressure.

Lime can be used to treat soils in order to improve their workability and load-bearing characteristics in a number of situations. Quicklime is frequently used to dry wet soils at construction sites and elsewhere, reducing downtime and providing an improved working surface.

An even more significant use of lime is in the modification and stabilization of soil beneath road and similar construction projects. Lime can substantially increase the stability, impermeability, and load-bearing capacity of the subgrade. Both quicklime and hydrated lime may be used for this purpose. Application of lime to subgrades can provide significantly improved engineering properties.

Over the last few years, there has been an increase in the use of waste lime and urea, resulting in a commensurate increase in plastic trash. However, only a small percentage of such compounds are reused and recycled, and the rest are either stored or discarded.

In order to enhance properties of weak soil formations (for example: deep loose sand deposits), a wide range of ground improvement techniques have been introduced over the past decades. Majority of these ground improvement techniques utilize mechanical energy and/or man-made binders like Ordinary Portland Cement (OPC), both of which require substantial energy for material production and/or installation. Moreover, injection and grouting techniques have been used to improve soils by injecting chemical materials into the pore space to bind soil particles together Nowadays, there is a high demand for new sustainable methods to improve soils. Over the last decade, extensive research has been undertaken to find alternative soil binders to replace OPC for soil improvement. Among other alternatives, calcite precipitation has been intensively investigated as a sustainable alternative for soil improvement and soil grouting. There are several techniques used to induce calcite precipitation, including urea hydrolysis, microbial denitrification, and sulfate reduction.

II.LITERATURE SURVEY

1. Mohammed Faizan (2013) in his literature review provides a comprehensive overview of soil stabilization using lime, highlighting the alteration of soil properties to enhance engineering characteristics. The objectives encompass increasing bearing capacity, weathering resistance, and permeability.
2. Shahzada Omer Manzoor and Adil Yousuf (2020) in their research paper provides a comprehensive exploration of soil stabilization using waste lime, addressing the imperative need for stabilizing problematic soils in construction amidst environmental concerns and limited land resources.
3. Asif Ali and Dr. Rakesh Gupta (2017) in their literature review studied the use of lime as a chemical stabilizer for compacted soil in the construction of flexible pavements. The study focuses on determining the optimal percentage of lime to be mixed with silty sand samples based on maximum unconfined compressive strength (UCS). Various geotechnical properties of unmodified soil samples are discussed, including colour, natural water content, liquid limit, plastic limit, plasticity index, optimum moisture content, maximum dry density, and unconfined compressive strength.
4. Mohamed Arab (2019) in literature review explains soil stabilization techniques using calcium carbonate precipitation through urea hydrolysis, with a focus on Microbially Induced Calcite Precipitation (MICP) and Enzyme Induced Calcite Precipitation (EICP). These techniques enhance soil properties by introducing calcite to fill pores and bind soil particles.

III.METHODOLOGY

1.1 Collection of Soil Sample

Collecting soil samples is an important step in understanding the health and composition of your soil. This information can be used to make informed decisions about fertilization, irrigation, and other land management practices.

There are a few different methods for collecting soil samples, and the best method for you will depend on the size and type of area you are sampling, as well as your budget.

Fig 3.1: Collection of Soil Sample

3.2 Different Laboratory Tests

3.2.1. The Grain Size Analysis Tests by Dry Sieving

A set of sieves was used to sieve the dirt. Sieve cloth is usually constructed of spun brass, phosphor bronze, or stainless steel. Sieves are classified by the size of the square opening in mm or microns, according to IS: 1498-1970. There are sieves ranging in size from 80mm to 75 microns available.

The grain size analysis test is performed to determine the percentage of each size of grain that is contained within a soil sample, and the results of the test can be used to produce the grain size distribution curve. This information is used to classify the soil and to predict its behavior. Sieve analysis is a method that is used to determine the grain size distribution of soils that are greater than 0.075 mm in diameter. It is usually performed for sand and gravel but cannot be used as the sole method for determining the grain size distribution of finer soil. The sieves used in this method are made of woven wires with square openings.

Apparatus

1. 1st set of sieves of sizes 30 mm, 80 mm, 40 mm, 20 mm, 10 mm and 4.75 mm.
2. 2nd set of sieves of size 2 mm, 850micron, 425micron, 150 micron and 75micron.
3. Balance of 0.1 g sensitivity along with weights and weight box.
4. Mechanical sieve shaker.

Procedure

1. For soil samples of soil retained on 75 micron I.S sieve
2. The proportion of soil sample retained on 75 micron I.S sieve is weighed and the recorded weight of the soil sample is as per I.S 2720.
3. I.S sieves are selected and arranged in the order as shown in the table.
4. The soil sample is separated into various fractions by sieving through above sieves placed in the above-mentioned order.
5. The weight of soil retained on each sieve is recorded.
6. The moisture content of soil if above 5% is to be measured and recorded.
7. No particle of soil sample shall be pushed through the sieves.

Fig. 3.2: Procedure of Sieve Analysis

3.2.2 Liquid Limit Test

The liquid limit is the moisture content at which the groove, formed by a standard tool into the sample of soil taken in the standard cup, closes for 10 mm on being given 25 blows in a standard manner. This is the limiting moisture content at which the cohesive soil passes from liquid state to plastic state.

From the results of liquid limit the compression index may be estimated. The compression index value will help us in settlement analysis. If the natural moisture content of soil is closer to liquid limit, the soil can be considered as soft if the moisture content is lesser than liquids limit, the soil can be considered as soft if the moisture content is lesser than liquid limit.

Apparatus

1. Balance
2. Casagrande's Liquid limit device
3. Grooving tool
4. Mixing dishes

5. Spatula
6. Electric Oven

Procedure

1. Put 250 gm of air-dried soil, passed through a 425 mm sieve, into an evaporating dish. Add distilled water into the soil and mix it thoroughly to form a uniform paste. (The paste shall have a consistency that would require 30 to 35 drops of cup to cause closure of standard groove for sufficient length.)
2. Place a portion of the paste in the cup of Liquid Limit device and spread it with a few strokes of a spatula.
3. Trim it to a depth of 1 cm at the point of maximum thickness and return excess soil to the dish.
4. Using the grooving tool, cut a groove along the centerline of the soil path in the cup, so that a clean sharp groove of proper dimension (11 mm wide at top, 2 mm at bottom, and 8 mm deep) is formed.
5. Lift and drop the cup by turning crank at the rate of two revolutions per second until the two halves of soil cake come in contact with each other for a length of about 13 mm by flow only, and record the number of blows.

Fig. 3.3: Procedure Of Liquid Limit

EXPERIMENTAL RESULTS

Sieve Analysis

Table 4.1: Sieve Analysis

S Sieve size (mm)	Weight Retained (kg)	% Weight Retained	Cumulative % Weight Retained	%Finer
4.75	1.6	80	80.00	20
2.36	0.194	9.7	89.70	10.3
1.18	0.082	4.1	93.80	6.2
0.85	0.059	2.95	96.75	3.25
0.6	0.029	1.45	98.20	1.8
0.425	0.005	0.25	98.45	1.55
0.3	0.01	0.5	98.95	1.05
0.15	0.009	0.45	99.40	0.6
0.075	0.007	0.35	99.75	0.25
Pan	0.005	0.25	100.00	0
	2		955.00	

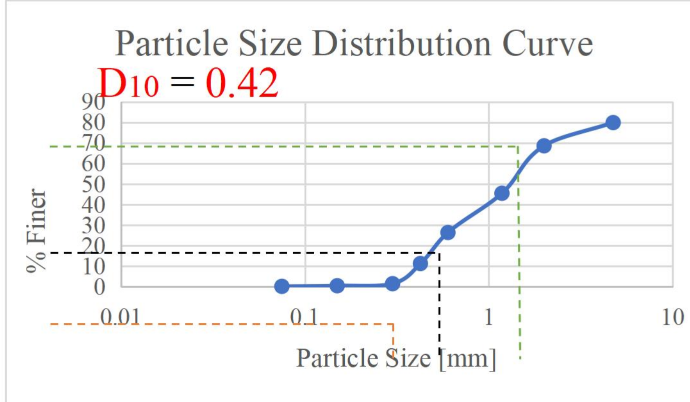

Fig 4.1: Sieve Analysis Graph

Table 4.2: Readings of Compaction Test

I	Container No .	1	2	3	5	6	7	8	10
II	Determination No.	1	2	3	4	5	6	7	8
III	Water content (%)	8	12	16	20	24	28	32	36
IV	Volume of mould (cm^3) (V)	1000	1000	1000	1000	1000	1000	1000	1000
V	Weight of Mould (kg)	3.72	3.72	3.72	3.72	3.72	3.72	3.72	3.72
VI	Weight of Mould + compacted soil(kg)	5.23	5.24	5.25	5.32	5.43	5.53	5.6	5.52
VII	Weight of compacted soil (w) (kg)	1.51	1.52	1.53	1.6	1.71	1.81	1.88	1.8
VIII	Bulk density (g/cm^3)	1.51	1.52	1.53	1.6	1.71	1.81	1.88	1.8
IX	Weight of Empty container (g) [w1]	14.65	13.73	13.91	12.52	12.4	14.34	12.68	14.68
X	Weight of container +wet soil (g) [w2]	36.61	41.99	42.93	26.97	28.4	29.21	32.76	38.2
XI	Weight of container+ dry soil (g) [w3]	34.77	38.95	38.99	24.46	25.5	25.87	27.43	32.2
XII	Moisture content (w) %	9.15	12.05	15.7	21.02	22.14	28.97	36.13	34.25
XIII	Dry density (g/cm^3)	1.38	1.36	1.32	1.32	1.4	1.4	1.38	1.34

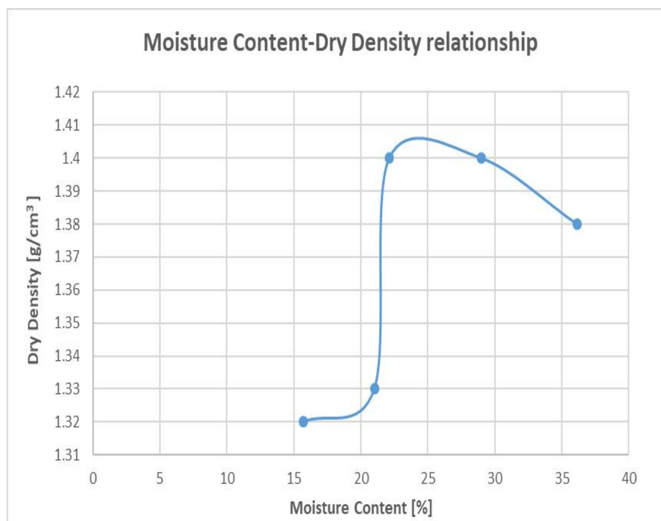

Fig 4.2: Compaction Test Graph

Table 4.3: pH of Soil

S.N.	Soil Sample	pH Value
1	Without Soil Stabilizer	8.2
2	With Soil Stabilizer	11.9

Table 4.4: Results of all Test

PROPERTY	VALUE	RANGE
Coefficient of Uniformity (Cu)	3.928 %	< 4
Coefficient of Curvature (Cc)	0.7 %	< 1
Liquid limit (Wl)	71.75%	-
Plastic limit (Wp)	27.77%	-
Plasticity index (Ip)	43.98%	-
Soil type as per AASHTO Classification	CH	-
Specific gravity	2.38	-
pH of soil	8.2	-
Maximum dry density (MDD)	1.405 Kg/m3	-
Optimum moisture content (OMC)	24%	-
pH of soil with additives	11.9	-
Unconfined Compression Test	0.56kg/cm2	-

Table 4.5: Different samples with % urea and % Waste lime

Sr. No.	Sample No.	% Urea	% Waste Lime
1	1	-	-
2	2	3	6
3	3	5	10
4	4	7.5	15
5	5	10	20

IV.CONCLUSION

1. From the basic tests of soil 'CH' soil type is determined.
2. The UCS value of CH soil without additives is found to be 0.27 kg/cm2.
3. The UCS value of CH soil is increased with varying proportion of waste lime and urea.
4. The maximum UCS value achieved is 0.56 kg/cm2.
5. The optimum percentage of additives is found to be 8% for urea and 16% for waste lime.

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