Experimental study on stabilisation of clayey soil by using Fly Ash and Sisal fiber

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Abstract

Earth has been used for building for thousands of years throughout the world spanning a diverse range of climates and cultures. Earth itself is a multi-component system usually consisting of stones, sand, silt, clay, water and, near the ground surface, organic humus. Structural stability of earth buildings is maintained by the structural integrity of the sand and stone framework, by the pore filling capacity of the silt and most importantly, by the binding qualities of the clay, which are in turn influenced by the moisture content of the soil. Compared with some building materials earth can be considered to have some disadvantages – it has relatively low compressive strength, tensile strength and abrasion resistance. It may also lose a lot of its rigidity in the presence of water. Nevertheless, it is very cheap, very widely available, environmentally friendly, strongly linked to local cultures and traditions and, with skillful construction, can contribute significantly to the aesthetic appeal and user comfort of buildings. In the present study attempt has been made to increase the strength of soil. In this research paper we performed various test on soil to know its properties or strength by using agricultural waste material such as Fly Ash as a stabilized material in soil with varying percentages 10%, 20%, 30%,40%. Use of Sisal Fibre for improving soil property is advantageous because they are cheap, locally available and eco-friendly. In this study, the stabilizing effect of Sisal Fibre on soil properties has been Experimental studied. Keeping this in view an experimental study is conducted on locally available i.e. expensive soil mixed with varying percentage of Sisal fibre. Soil samples for California bearing ratio (CBR) tests and UCS are prepared at its maximum dry density(MDD) corresponding to its optimum moisture content (OMC) in the CBR mould and UCS sampler without and with Sisal fibre. The percentage of Sisal fibre by dry weight of soil is taken as 0.25%, 0.50%, 0.75% and 1% and corresponding to each Sisal fibre content soaked CBR tests and UCS tests are conducted in the laboratory. Tests result indicates that soaked CBR and UCS value of soil increases with the increase in Sisal fibre content. Adding of sisal fibre and Fly Ash results in less thickness of pavement due to increase in CBR of mix and reduce the cost of construction and hence economy of the construction of highway will be achieved. This is because of composite effect of sisal fibre and Fly Ash changes the brittle behaviour of the soil to ductile behaviour.

Keywords

Clayey Soil, Fly Ash, Sisal Fiber, Soil Stabilization

INTRODUCTION

Soil is the uppermost unconsolidated material of the earth present naturally in the universe. It is formed by the decomposition of rocks under the influence of naturally occurring conditions such as wind, rain, snow, heat, etc. It is abundantly available and is the cheapest construction material. It is a complex material because of its highly variable composition and characteristics. The characteristics of soil change according to topography and its location. For safer construction the properties of soil should match with the design requirements of an engineering structure. Geotechnical engineer plays an important role in this work for checking whether the requirements of the structure are fulfilled by the soil or not. Construction of engineering structures on poor soil involves a great risk. These soils show settlements, low shear strength and high compressibility.

Very often the available soil is not suitable for construction purposes.Strength, permeability and stability on slopes are the main aspects of soil that we have to deal with. For studying the engineering behaviour of soil, we have to deal with the stability of underground structures, retaining structures, foundations, slopes, earth dams and pavement construction.

LITERATURE REVIEW

Prabakar J. and Sridhar R.S. (2002) used randomly distributed sisal fiber as reinforcement in black cotton soil at four different percentages of fiber, i.e. 0.25, 0.5, 0.75 and 1% by weight of dry soil and four different lengths of fiber, i.e. 10, 15, 20 and 25 mm and found significant improvement in the shear strength parameters (c and ϕ) of the soil and concluded that the increase in fiber length and fiber content in soil causes reduction in the OMC and dry density. The cohesion improved linearly with fiber content up to 0.75% and shear

strength increased with increasing length of fiber up to 20 mm.

Fajobi A.B. et al. (2005)
performed compaction test, CBR test and UCS test on expansive clay. They varied cement and fly ash from 1% to 11% each with 1% increase at a time. They concluded that addition of 9% cement plus 3% fly ash gave MDD of 1604 kg/m^3 and OMC of 16%, and produced shear strength increase in CBR values to 15.86 and 18.70% for unsoaked and soaked samples and shearing resistance of 291.61 kg/m^2 for uncured sample and 1756.13 kg/m^2 for cured sample.

Abdi et al. (2008)
worked on fiber reinforced soils and evaluated that consolidation settlement, swelling and crack formation reduces substantially in clayey soil. They reported a marginal increase in hydraulic conductivity on increasing polypropylene fiber content and fiber length in the mix. Shrinkage limit of the clay soil reinforced with fibers was significantly increased as a result of increasing the fiber content and length.

Singh Baleshwar (2011)
performed compaction test and UCS test on clayey-silt. He showed the effects of using low calcium fly ash and ordinary portland cement in improving the strength of a clayey silt soil. He determined that with increment of fly ash in soil, MDD decreases and OMC increases. When only fly ash is added, the soil mixes are to be used for constructing road embankments and subgrade layer of pavements. When 1% cement is added to the soil-fly ash mixes, these are be used even for sub-base of low-volume roads.

Manjunath K.R. et al. (2013) studied the effect of sisal fiber on compaction and strength characteristics of black cotton soil treated with lime. They reported that for a particular fiber percentage, the MDD of stabilized soil increases and OMC decreases. The maximum dry density and OMC of sisal fiber reinforced soil increased with 3% lime. 3% of lime content and 0.75% sisal fiber were considered as optimum percentage for black cotton soil to increase the California bearing ratio value.

Savitha A.L. et al. (2013) conducted compaction tests and UCS tests on Black Cotton soil using coarse and fine fly ash. They varied the percentage of flyash from 5% to 25% with increase of 5% at a time. Curing was done for 1,7,14,28 days. They reported that the strength obtained by fine fly ash was 25% more than that of coarse fly ash.On increasing water content upto 30%, the dry density decreases and if water content is increased further the dry density decreases gradually.The MDD was 1.35 g/cc for 5% fly ash mixed with 95% soil and lowest density was 0.6g/cc for 30% fly ash mixed with 70% soil.

Agrawal M.L. et al. (2013) performed compaction tests and CBR test on black cotton soil. They varied the percentage of flyash from 10% to 50% with increase of 10% at a time.They investigated that the MDD increases with increment in fly ash up to 20% , and with more addition it decreases. The increase in CBR value and dry density is maximum for 30% fly ash mixture with black cotton soil. On increasing percentage of fly ash, there is decrease in the the liquid limit of black cotton soil, resulting in reduced swelling of soil.

Ruprai B.S. et al (2013) conducted compaction test and California bearing ratio test on black cotton soil. They used varying percentages of fly ash i.e. 10, 20, 30, 40, 50% and observed the effect of fly ash on moisture –density relationship and CBR value of soil. They reported that as compared to other mixes the CBR value is higher for 20% fly ash.Moreover the dry density was also more at 20% fly ash content.

Yanbin Li et al. (2014) performed compaction test and triaxial shear test on silty clay. They used 0.5%, 1%, 1.5% sisal fiber with lengths 5mm, 10mm and 15 mm. They reported that the stress increased with increase in strain when 1.0% fiber content is taken and they observed no decrease in stress when the strain exceeded 1.0%.They reported that silty clay reinforced with sisal fiber has 20% more strength than non-reinforced clay when 1.0% fiber content of length 10 mm is considered.

Kumar R. et al. (2014)studied the effect of sisal fibers on the UCS value of bentonite. He reported that there can be an increase in the UCS value of bentonite by adding lime, phosphogypsum and sisal fibers. The highest UCS value was obtained at 8% lime, 8% phosphogypsum and 1% sisal fibers. UCS value increased with increment in fiber from 0.5 to 2% fiber.

Abadi et al. (2014) conducted compaction test and California bearing ratio test on clay. He varied the percentage of flyash from 5% to 25% with increase of 5% at a time. He reported that the MDD of clay increased with increment in ash till 15%, then decreased to 1.53 at 20% ash. The OMC decreased until 15 %,then after that it started to increase. CBR value reduces slightly when soil ash mixture contains more than 15% ash.

MATERIALS AND METHODS

SOIL

Source of soil

The soil used in this studywas obtained from village Panglian near Kohara in district Ludhiana. As per IS classification of soil, the soil used is low

compressibility silt. The soil properties are given in the table as under:

Properties of soil used in the study

S. No.	Properties of soil	Value
1	Specific gravity	2.68
2	Liquid Limit (%)	29
3	Plastic Limit (%)	24
4	Plastic Index (%)	5
5	Classification of soil(According to ISC)	ML (Silt of Low Compressibility)
6	Maximum Dry Density (kN/m^3)	17.2
7	Optimum Moisture Content (%)	14
8	CBR (soaked)	2.67
9	Unconfined compressive strength (kN/m^3)	178.6

3.4.2 FLY ASH

Source of Fly ash

Fly ash used in this research work was collected from Guru Gobind Singh Super Thermal Plant, Rupnagar. The fly ash was dried in oven and then it was sieved for the removal of foreign particles.. Properties and composition of fly ash as obtained from the thermal plant shown in table no. 3.2 and 3.3

Engineering Properties of Fly ash (Source: Guru Gobind Singh Thermal Plant, Rupnagar)

S. No	Properties of fly ash	Value
1	Colour	Whitish Grey
2	Specific Gravity	2.2
3	Liquid limit	45
4	Maximum dry density (kN/m^3)	12.24
5	Optimum moisture content (%)	36

Chemical Composition of Fly Ash

S. No	Name of constituent	Percentage
1	Silica (SiO_2)	63.93
2	Alumina (Al_2O_3)	23.72
3	Iron Oxide (Fe_2O_3)	7.93
4	Calcium Oxide (CaO)	2.12
5	Magnesium oxide (MgO)	1.22
6	Potassium oxide (K_2O)	1.08

SISAL FIBRE

Source of sisal fiber

The sisal fiber used in this study was obtained from Jindaram Exports, Sirsa. Sisal is a natural fiber having greater tensile strength and can be used as an effective reinforcing material in soil stabilization. The properties and composition of sisal fiber are discussed in table.

Properties of Sisal Fiber (Source: Jindaram Exports, Sirsa)

S. No	Property	Value
1	Colour	White
2	Specific Gravity (Kg/ m^3)	1370
3	Water Absorption (%)	110
4	Length of fiber (mm)	30
5	Diameter of sisal fiber (mm)	0.2
4	Tensile Strength(MPa)	347
5	Modulus of elasticity (GPa)	15

Chemical Composition of Sisal Fiber (Source: Jindaram Exports, Sirsa)

S .No	Component	Percentage
1	Cellulose	71.5
2	Hemicelluloses	18.1
3	Lignin	5.9
4	Pectin	2.3
5	Waxes	0.5
6	Water Soluble Matter	1.7

EXPERIMENTAL PROGRAMME

The experimental programme for this study includes the processing of materials and their mix proportion to be used for finding various engineering properties of soil- fly ash- sisal fiber mix. The procedure for conducting tests i.e. standard proctor test, California bearing ratio test, unconfined bearing ratio is discussed in this chapter. All the tests were conducted according to IS code

Processing of materials

Sufficient quantity of soil was taken from these bags and dried in oven for conducting each test. In the same manner fly ash was collected and oven dried for 24 hours. The desired quantity of fly ash was taken and mixed uniformly with the soil. The desired

amount of sisal fiber was then added to the soil- fly ash mix. Due care was taken so that a uniform soil-fly ash- sisal fiber mixture can be obtained.

3.5.3 Laboratory tests

The following tests were performed for the present study:

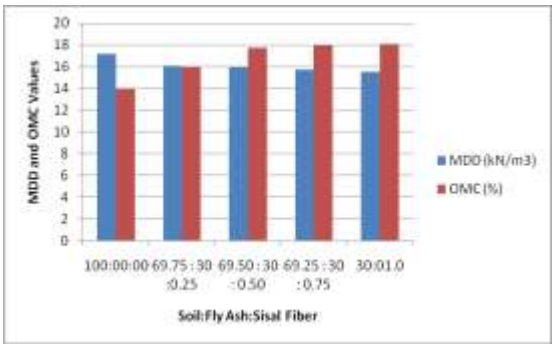
1. Pycnometer test
2. Liquid Limit test
3. Plastic Limit test
4. Standard Proctor test
5. California bearing ratio test
6. Unconfined compressive strength test

Mix proportions of Soil(S), Fly Ash (FA) and Fiber(F)

S.NO	DESIGNATION (S:FA:F)
1	100:0:0
2	90:10:0
3	80:20:0
4	70:30:0
5	60:40:0
6	69.75:30:0.25
7	69.50:30:0.50
8	69.25:30:0.75
9	69:30:1

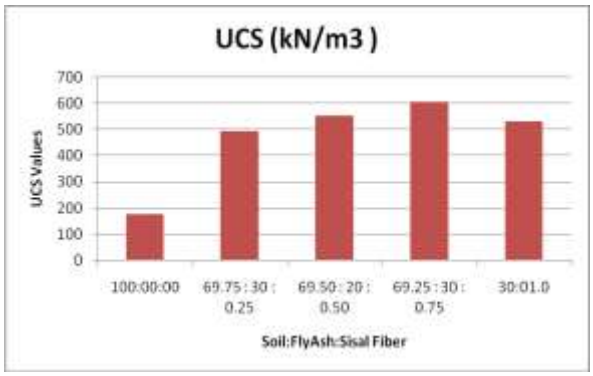
STANDARD PROCTOR TEST

Proportion Soil : Fly ash : Sisal fiber	MDD (kN/m^3)	OMC (%)
100:0:00	17.2	14
69.75 : 30 :0.25	16.1	16
69.50 : 30 : 0.50	15.9	17.7
69.25 : 30 : 0.75	15.7	18
69 :30 : 1.0	15.5	18.1



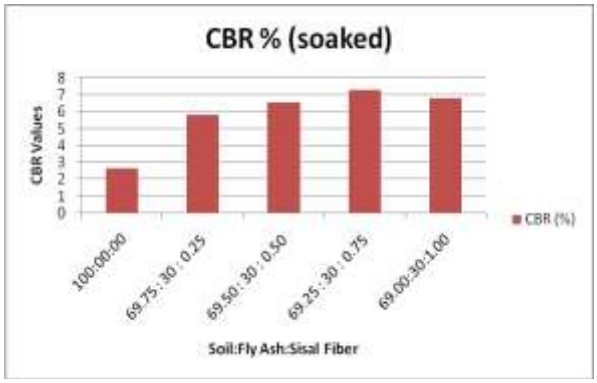
UNCONFINED COMPRESSIVE STRENGTH TEST

(Soil : Fly ash : Sisal Fiber)	UCS (kN/m^2)
100:00:00	178.6
69.75 : 30 : 0.25	495.4
69.50 : 20 : 0.50	552.9
69.25 : 30 : 0.75	607.3
69 : 30 : 1.0	530.8



CALIFORNIA BEARING RATIO TEST (SOAKED)

Proportion Soil : Fly ash	CBR (%)
100:00:00	2.67
69.75 : 30 : 0.25	5.83
69.50 : 30 : 0.50	6.56
69.25 : 30 : 0.75	7.29
69 : 30 : 1.0	6.81



CONCLUSIONS

The conclusions drawn from the experimental investigation are as under:

- When percentage fly ash increases in soil there is increase in O.M.C. and decrease in M.D.D.
- With the increase in quantity of sisal fiber the value of O.M.C. increases and M.D.D. decreases.
- The optimum value of fly ash to be used for further work was 30%.
- The best ratio obtained was 69.25% soil: 30% fly ash: 0.75% sisal fiber.
- Soaked CBR value increases from 2.67% for virgin soil to 7.29% for the best ratio of the mix.
- Unconfined compressive strength of soil-fly ash mixtures increase with increase in sisal fiber up to 0.75 % by weight.

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