International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

Soil Stabilization using Plastic

Dr. Babitharani.H, Ashwini D G, Pavan siva kumar.Ch, Dimple Bahri, Koushik.B, Sindhu Shankar
Department of Civil Engineering, SET, Jain University, India.

ABSTRACT

Soil stabilization is a process which improves the physical properties of the soil, such as increasing in shear strength, bearing capacity etc. Which can be done by the use of controlled compaction or addition of suitable mixtures like cement, lime, and waste materials like fly ash, phosphogypsum etc. The cost of introducing these additives has also increased in recent years which opened the door widely for the other kinds of soil additives such as plastic, bamboo etc. This new technique of soil stabilization can be effectively used to meet the challenges of the society to reduce the quantities of waste, producing useful stabilization from plastic waste. Use of plastic products such as polythene bags, bottles etc., is increasing day by day leading to various environmental concerns. Therefore, the disposal of plastic wastes without causing any ecological hazards has become a real challenge. Thus, using plastic as soil stabilizer is an ecological utilization since there is scarcity of good soil for construction. This project involves the study on the possible use of waste plastic.

INTRODUCTION

Soil deposits in nature exist in an extremely irregular manner producing thereby an infinite variety of combination which will affect the strength of the soil and many procedures to make it purposeful.

Soil stabilization is the process of altering some soil properties by different methods, mechanical or chemical in order to produce an improved soil material which has all the desired engineering properties. Soils are generally stabilized to increase their strength and durability or to prevent soil erosion. The properties of soil vary a great deal at different places or in certain cases even at one place the success of soil stabilization depends on soil testing. Various methods are there to stabilize soil and the method should be verified in the lab with the soil material before applying it on the field.

Dr. A. I. Dhatrak in 2015 after reviewing performance of plastic waste mixed soil as a geotechnical material. It was observed that for construction of flexible pavement to improve the sub grade soil of pavement using waste plastic bottles chips is an alternative method.

AKSHAT MALHOTRA & HADI GHASEMAIN in 2014 studied the effect of HDPE plastic waste on the UCS of soil. In a proportion of 1.5%, 3%, 4.5% and 6% of the weight of dry soil, HDPE plastic waste was added. They concluded that the UCS of black cotton soil increased on addition of plastic waste.

CHOUDHARY, JHA & GILL in 2010 demonstrated the potential of HDPE to convert as soil reinforcement by improving engineering properties of sub grade soil.

RAJKUMAR NAGLE in 2014 performed CBR studied for improving engineering performance of sub grade soil. They mixed polyethylene, bottles, food packaging and shopping bags etc., as reinforcement within black cotton soil, yellow soil and sandy soil.

MERCY JOSEPH POWETH in 2013 investigated on safe and productive disposal of quarry dust, type of waste and wastes-plastic by using them in the pavements sub grade. In their paper, a series of CBR and SPT test were carried out for finding the optimum percentages of waste plastics, quarry dust in soil sample.

ACHMAD FAUZI in 2016 calculated the engineering properties by mixing waste plastic High Density Polyethylene (HDPE) and waste crushed glass as reinforcement for sub grade improvement.

CHEBET in 2014 did laboratory investigations to determine the increase in shear strength and bearing capacity of locally available sand due to random mixing of strips of HDPE (high density polyethylene) material from plastic shopping bags.

Principles of Soil Stabilization:

• Evaluating the soil properties of the area under consideration.

• Deciding the property of soil which needs to be altered to get the design value and choose the effective and economical method for stabilization.

• Designing the Stabilized soil mix sample and testing it in the lab for intended stability and durability values.

NEEDS AND ADVANTAGES

Soil properties vary a great deal and construction of structures depends on the bearing capacity of the soil hence, we need to stabilize the soil which makes it easier to predict the load bearing capacity of the soil. The gradation of the soil is also a very important property to keep in mind while working with soils. The soils may be well-graded which is desirable as it has less number of voids or uniformly graded which though sounds stable but has more voids. Thus, it is better to mix different types of soils together to improve the soil strength properties.

- It improves the strength of the soil, thus, increasing the soil bearing capacity.
- It is more economical both in terms of cost and energy to increase the bearing.
- Capacity of the soil rather than going for deep foundation or raft foundation.
- Sometimes soil stabilization is also used to prevent soil erosion or formation of dust.
- Which is very useful especially in dry and arid weather Stabilization is also done for soil water-proofing.
- It helps in reducing the soil volume change due to change in temperature or moisture content.
- Stabilization improves the workability and the durability of the soil.

MATERIALS ABD METHODS

MATERIALS

In this research work conducted various experiment to find the stabilization of the sub base using the industrial waste and plastic waste the various test conducted to find the stabilization of the sub based on the ASTM procedure are listed:1. Liquid Limit, 2. Plastic Limit, 3. Shrinkage limit, 4. Specific Gravity.

1. LIQUID LIMIT: Liquid limit is defined as the moisture content at which soil begins to behave as a liquid material and begins to flow. The importance of the liquid limit test is to classify soils. Different soils have varying liquid limits. Also, once must use the plastic limit to determine its plasticity index.

2. PLASTIC LIMIT: Plastic limit is defined as the moisture content and expressed as a percentage of the oven dried soil at which the soil can be rolled into the threads one-eight inch in a diameter without soil breaking into pieces. This is also the moisture content of a solid at which a soil changes from a plastic state to a semisolid state.

3. SHRINKAGE LIMIT: This breaking point is accomplished when further loss of water from the soil does not reduce the volume of the soil. It can be defined more precisely as the least water content at which the soil can in any case be completely saturated.

4. SPECIFIC GRAVITY: Specific gravity is defined as the ration of the unit of soil solids unit of water. The specific gravity is needed for various calculation purposes in soil mechanics, e.g. void ratio, density.

METHODS

MECHANICAL METHODS OF STABILIZATION

In this procedure, soils of different gradations are mixed together to obtain the desired property in the soil. This may be done at the site or at some other place from where it can be transported easily. The last blend is then compacted by the regular strategies to get the required thickness.

ADDITIVE METHOD OF STABILIZATION

The addition of manufactured products into the soil, which in appropriate amounts improves the nature of the soil. Materials such as cement, lime, bitumen, fly ash etc., are used as synthetic additives. Sometimes different fibers are also used as reinforcements in the soil.

Oriented fiber reinforcement the fibers are arranged in some order and all the fibers are placed in the same orientation. The fibers are laid layer by layer in this type of orientation. Continuous fibers in the form of sheets, strips or bars etc. are used systematically in this type of arrangement.

- It enhances the quantity of the soil hence, expanding the soil bearing limit.
- Stabilization enhances the workability and the strength of the soil.
- It helps in lessening the soil volume change.

METHODOLOGY

The materials which are considered are soil and plastic with chemical composition of polypropylene.

SCOPE OF WORK

The experimental work consists of the following steps,

1.Moisture content,

2.Specific gravity of the soil,

3.Determination of soil index properties (Atterberg Limits),

4.Liquid limit by Casagrande's apparatus,

5.Plastic limit,

6.Particle size distribution by sieve analysis,

7.Preparation of reinforced soil samples,

8.Determination of shear strength by:

a.Direct shear stress,

b.Unconfined compression test.

1. MOISTURE CONTENT

Soil mass is a porous structure, having void filled with water or air. Moisture content (W) is defined as the ratio of the mass of water (Wa) in voids to the mass of soil solids(Ws) expressed as a percentage thus:

W=Wa / Ws

2. SPECFIC GRAVITY

Specific gravity of soil particles is used in determination of voids ratio, porosity, degree of saturation and critical hydraulic gradient. It is also used in finding particle size by means of hydrometer analysis.

Acceptable Values of G -2.60-2.72 for course grained soils

-2.70-2.80 for fine grained soils

-2.30-2.50 for organic soils

3. LIQUID LIMIT BY CASAGRANE'S METHOD

The liquid limit (WL) is the minimum water content at which a part of soil is grooving tool of standard dimensions, will flow together for a distance of 13mm under the impact of 25 blows in a standard liquid limit apparatus, it is the water content at which the soil first shows a small shearing resistance as the water content is reduced.

WHY PLASTIC

Plastic increases the shear strength and tensile strength of soil. It can significantly enhance the properties of the soil used in the construction of road infrastructure and available abundance.

PROPERTIES OF PLASTIC

Plastic have a numerous properties that make them superior to other materials in many applications. The different types of properties are physical properties and chemical properties.

PHYSICAL PROPERTIES

Plastic has transparency, flexibility, elasticity, water resistant, electrical resistance and soft when it is hot. Soil is a naturally occurring material's that are used for the construction of all except the surface layers of pavements and that are subjected to classification tests to provide a general concept of their engineering characteristics.

CHEMICAL PROPERTIES Chemical resistance, thermal resistance, reactivity with water, flammability, heat of combustion etc., are the basic chemical properties of plastic.

RESULTS & DISCUSSIONS

Specific gravity

Soil sample - it was collected from a construction site near Banashankri III Stage

Sample number	1	2	3
Mass of empty bottle (M1) in gms	66.3	66.2	66.2
Mass of bottle + dry soil (M2) in gms	114.2	120	118
Mass of bottle + dry soil + water (M3) in gms	192.66	195.8	194.7
Mass of bottle + water (M4) in gms	165	165.1	165.2
Specific gravity	2.35	2.32	2.32

Table No: 1. Specific Gravity of Soil Sample

AVERAGE SPECIFIC GRAVITY = 2.33

Acceptable values of G = 2.60 – 2.72 for coarse grained soils

=2.70-2.80 for fine – grained soils

=2.30-2.50 for organic soils.

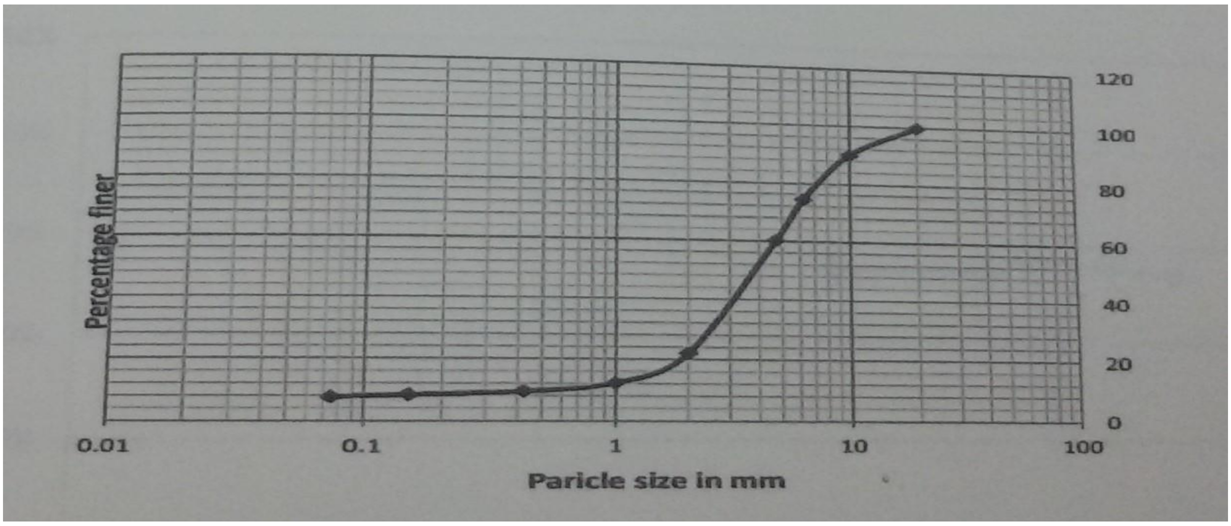
Since the result of the specific gravity of soil sample is 2.33. It comes under Organic Soil.

Sieve analysis

Sieve analysis observations and calculations of Soil Sample

IS sieve size	Mass retained(m/100)	Mass of soil retained (g) %	Cumulative retained (%)	Cumulative % finer (N)
1	2	3	4	5
20	0	0	0	100%
10	83.98	9.94	9.94	90.06%
6.25	126.41	14.56	24.9	74.4%
4.75	64.15	7.59	32.49	60.39%
2	447.58	52.97	85.46	22%
1	18.94	2.24	87.7	12.3%
0.425	29.91	2.83	90.43	9.471%
0.15	9.76	1.16	9169	8.32%
0.075	5.96	0.7	92.39	7.61%
Pan	64	7.57	99.96	0.04%

Table NO: 2 Sieve Analysis of Soil Sample



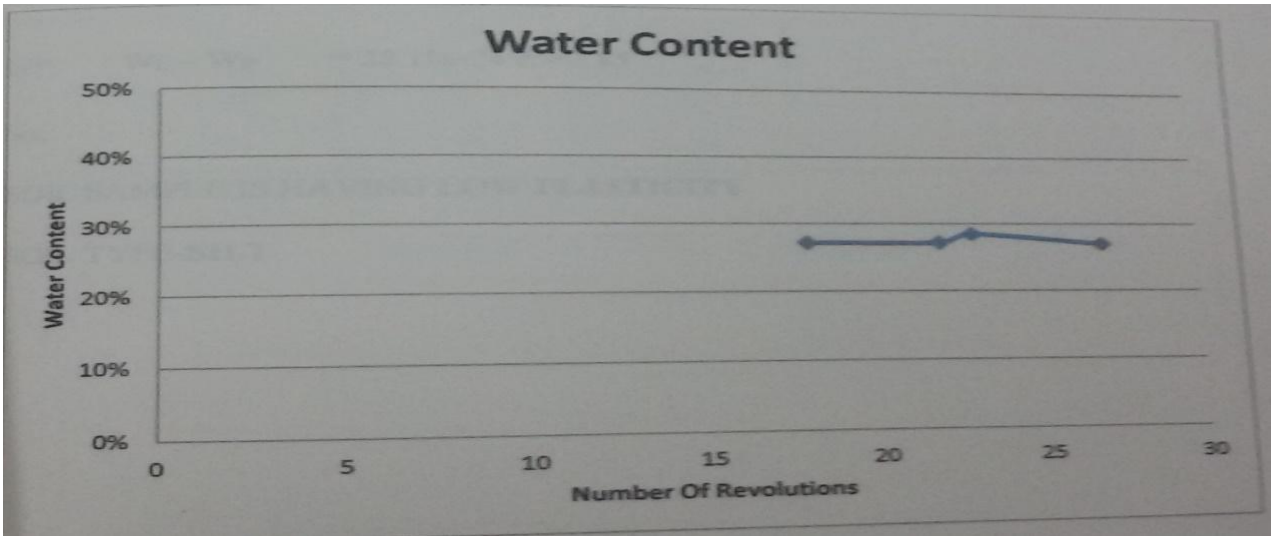
Graph No 1. Sieve Analysis

Liquid Limit

Observation no	1	2	3	4
Number of Revolutions	27	23	22	18
Crucible no	1	2	3	4
Wt. Of crucible wet soil(g)	20.94	21.1	21.6	21.4
Wt. of crucible +dry soil(g)	19.78	20	20.7	20.2
Wt. of crucible(g)	15.5	15.7	16	15.4
Wt. of water	1.16	1.2	1.2	1.2
Wt. of dry soil(g)	4.28	4.2	4.4	4.4
Water content (%)	27%	28.5%	27.2%	27.2%

Table No: 3. Liquid Limit of Soil Sample

AVERAGE LIQUID LIMIT WL = 28.1%



Graph No: 2. Water content of Soil Sample.

PLASTIC LIMIT

Observation No	1	2	3	4
Container No	1	2	3	4
Wt. of container + wet soil(g)	32.6	33.8	32.6	36.2
Wt. of container + dry soil(g)	30	31	29.7	33.4
Wt. of container(g)	19	16.2	18.5	22.3
Wt. of dry soil(g)	11	12.5	11.2	11.1
Wt. of water(g)	2.6	2.8	2.9	2.8
Plastic limit (wp)	23.63%	22.9%	25.8%	25.2%

Plastic Limit of Soil Sample

AVERAGE PLASTIC LIMIT=24.25%

PLASTICITY INDEX

IP = WL-WP = 28.1%-24.25% = 3.85%

So,

SOIL SAMPLE IS HAVING **LOW PLASTICITY**

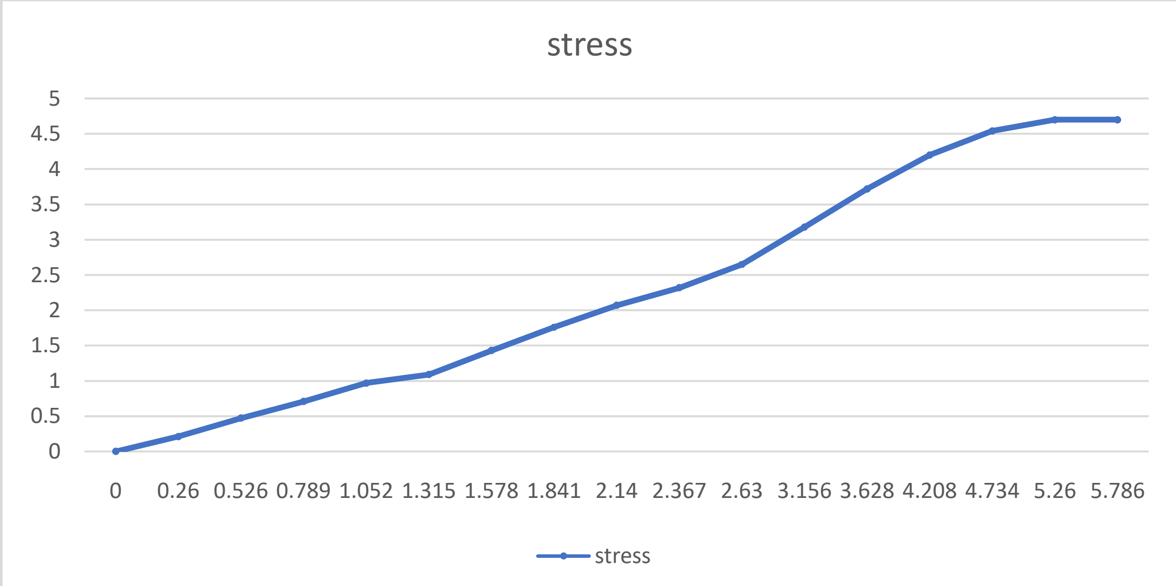
SOIL TYPE-**SILT**

UNCONFINED COMPRESSION TEST

SOIL SAMPLE

Dial gauge reading	Strain(c)	Proving ring	Reading corrected area	Load(N)	Axial stress(Kg/cm2)
0	0	0	11.330	0	0
20	0.26	8	11.364	2.4	0.211
40	0.526	18	11.398	5.4	0.473
60	0.789	27	11.420	8.1	0.709
80	1.052	37	11.450	11.1	0.969
100	1.315	42	11.480	12.6	1.09
120	1.578	55	11.510	16.5	1.430
140	1.841	68	11.540	20.4	1.760
160	2.140	80	11.570	24	2.070
180	2.367	90	11.600	27	2.320
200	2.630	103	11.630	30.9	2.650
240	3.156	124	11.700	37.2	3.180
280	3.628	146	11.760	43.8	3.720
320	4.208	166	11.830	49.8	4.200
360	4.734	180	11.890	54	4.540
400	5.260	191	11.960	57.3	4.700
440	5.786	190	12.020	57	4.700

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017



Axial Stress=4.7Kg/Cm2

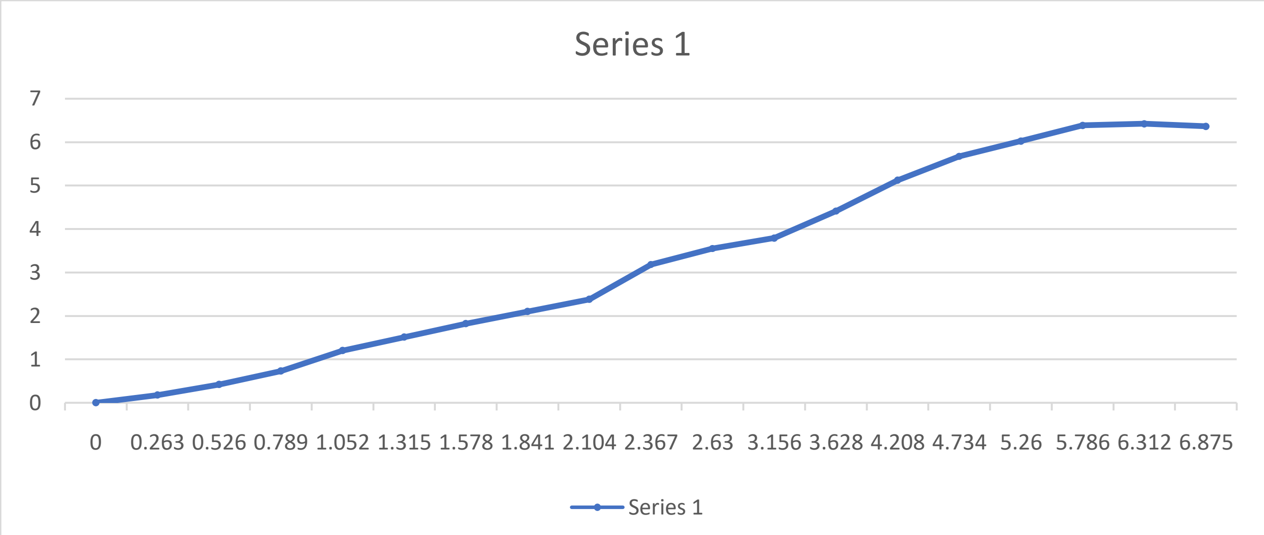
Axial Stress for Soil Sample With 0% Reinforcement

0.05% REINFORCED SOIL SAMPLE WITH POLYPROPYLENE

Dial gauge reading	Strain(c)	Proving ring	Reading corrected area	Load(N)	Axial stress (Kg/Cm2)
0	0	0	11.330	0	0
20	0.263	7	11.364	2.1	0.180
40	0.526	16	11.398	4.8	0.420
60	0.789	28	11.420	8.4	0.730
80	1.052	46	11.450	13.8	1.200
100	1.315	58	11.480	17.4	1.510
120	1.578	70	11.510	21	1.820
140	1.841	81	11.540	24.3	2.100
160	2.104	92	11.570	27.6	2.380
180	2.367	123	11.600	36.9	3.180
200	2.630	138	11.630	41.4	3.550
240	3.156	148	11.700	44.4	3.790
280	3.628	173	11.760	51.9	4.410
320	4.208	202	11.830	60.6	5.120
360	4.734	225	11.890	67.5	5.670
400	5.260	240	11.960	72	6.020
440	5.786	256	12.020	76.8	6.380
480	6.312	260	12.08	78	6.420
520	6.875	256	12.14	76.8	6.360

UCS Test for Soil Sample With 0.05% Reinforcement

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017



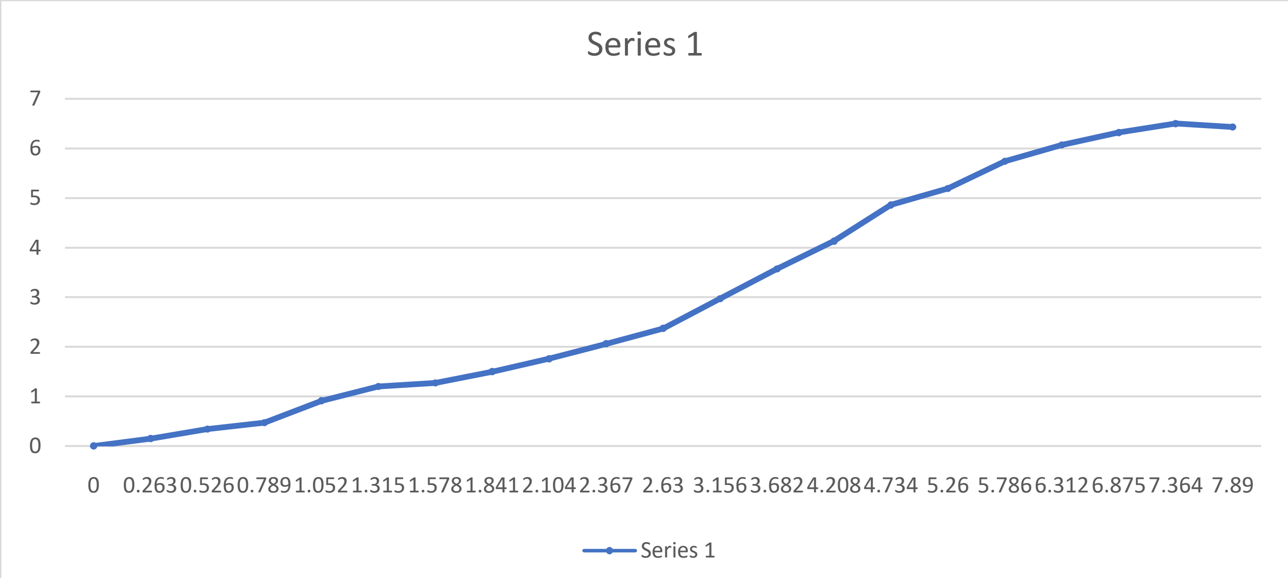
Axial Stress = 6.42 Kg/Cm2

Axial Stress for Soil Sample with 0.05% Reinforcement

0.15% REINFORCED SOIL SAMPLE WITH POLYPROPYLENE

Dial gauge reading	Strain(c)	Proving ring	Reading corrected area	Load(N)	Axial stress (Kg/Cm2)
0	0	0	11.330	0	0
20	0.263	6	11.364	1.8	0.150
40	0.526	13	11.398	3.9	0.340
60	0.789	18	11.420	5.4	0.470
80	1.052	35	11.450	10.5	0.910
100	1.315	46	11.480	13.8	1.200
120	1.578	49	11.510	14.7	1.270
140	1.841	58	11.540	17.4	1.500
160	2.104	68	11.570	21.4	1.760
180	2.367	80	11.600	24	2.060
200	2.630	92	11.630	27.6	2.370
240	3.156	116	11.700	34.8	2.970
280	3.682	140	11.760	42	3.570
320	4.208	163	11.830	48.9	4.130
360	4.734	193	11.890	57.9	4.860
400	5.260	207	11.960	62.1	5.190
440	5.786	230	12.020	69	5.740
480	6.312	245	12.08	73.5	6.070
520	6.875	256	12.14	76.8	6.320
560	7.364	264	12.20	79.2	6.500
600	7.890	263	12.26	78.9	6.430

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017



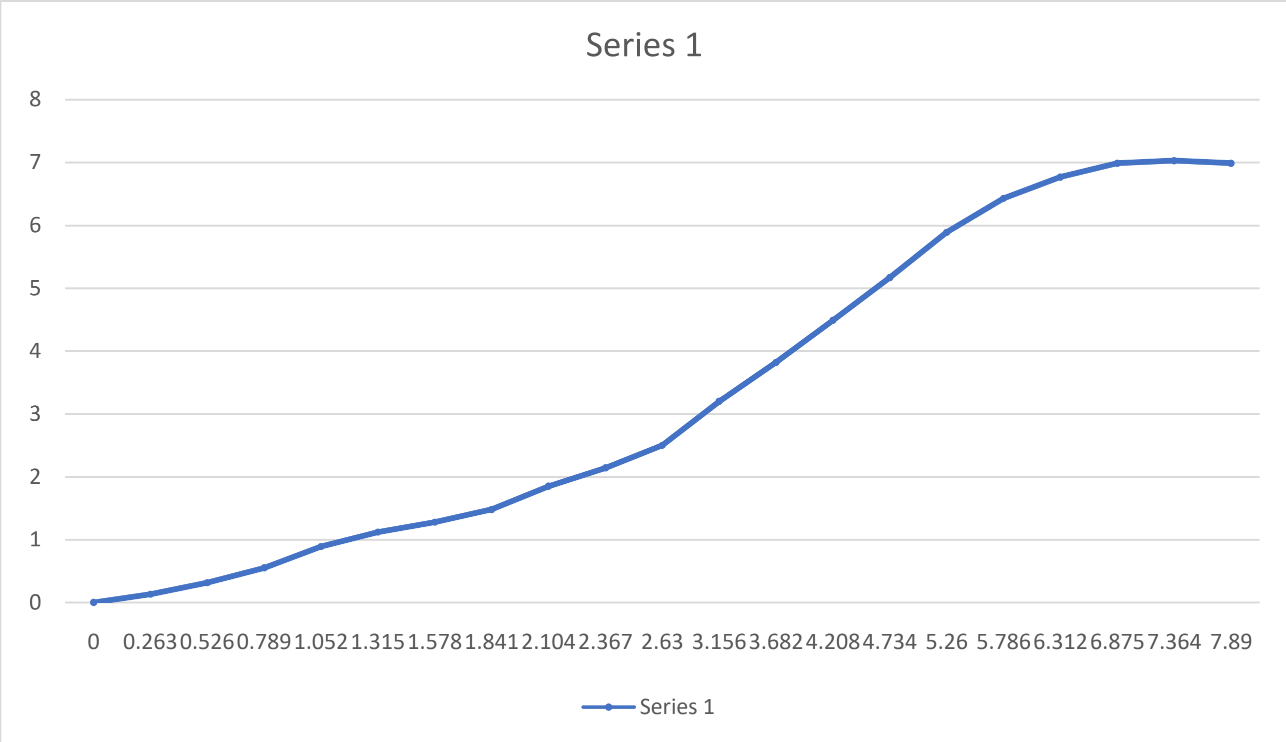
Axial Stress = 6.5 Kg/Cm2

Axial Stress for Soil Sample with 0.15% Reinforcement

0.25% REINFORCED SOIL SAMPLE WITH POLYPROPYLENE

Dial gauge reading	Strain(c)	Proving ring	Reading corrected area	Load(N)	Axial stress (Kg/Cm2)
0	0	0	11.330	0	0
20	0.263	5	11.364	1.5	0.131
40	0.526	12	11.398	3.6	0.315
60	0.789	21	11.420	6.3	0.550
80	1.052	34	11.450	10.2	0.890
100	1.315	43	11.480	12.9	1.120
120	1.578	49	11.510	14.7	1.277
140	1.841	57	11.540	17.1	1.480
160	2.104	70	11.570	21	1.850
180	2.367	83	11.600	24.9	2.140
200	2.630	97	11.630	29.1	2.500
240	3.156	125	11.700	37.5	3.200
280	3.682	150	11760	45	3.820
320	4.208	178	11.830	53.4	4.490
360	4.734	205	11.890	61.5	5.170
400	5.260	235	11.960	70.5	5.890
440	5.786	258	12.020	77.4	6.430
480	6.312	273	12.08	81.9	6.770
520	6.875	283	12.14	84.9	6.990
560	7.364	286	12.20	85.8	7.030
600	7.890	283	12.26	84.9	6.990

UCS Test for Soil Sample With 0.25% Reinforcement



Axial Stress = 7.03 Kg/Cm2

Axial Stress for Soil Sample with 0.25% Reinforcement

DIRECT SHEAR STRESS

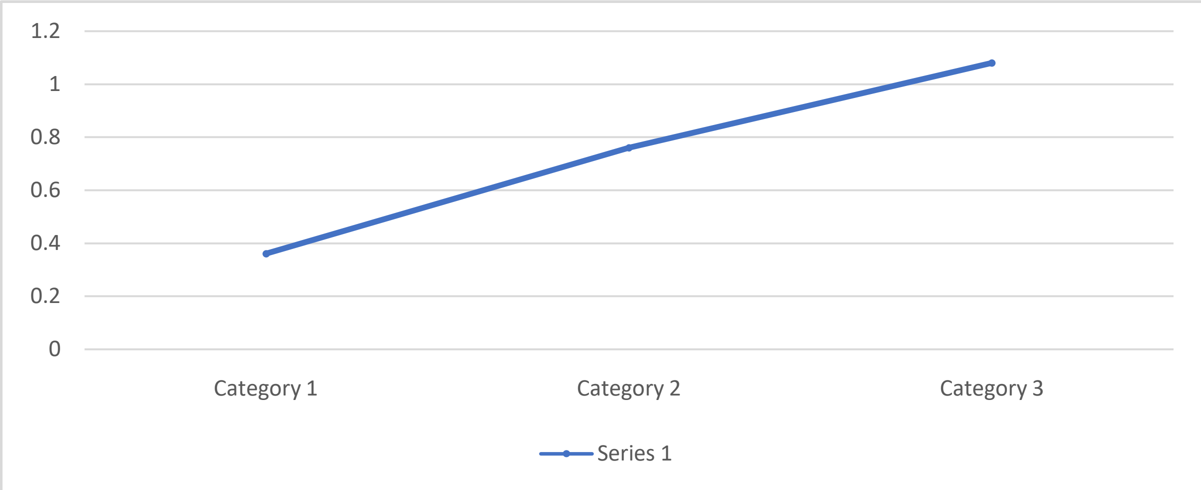
Volume of Shear Box	90 cm2
Maximum dry density of soil	1.76%
Optimum moisture content of soil	14%
Weight of the soil to be filled in the shear box	176.4 gms
Weight of water to be added	30 gms

SOIL SAMPLE

Sample No	Normal stress (Kg/Cm2)	Proving ring reading	Shear load (n)	Shear load (kg)	Shear stress (kg/cm2)
1	0.5	26	125.9	12.85	0.360
2	1.0	50	265.8	27.13	0.760
3	1.5	70	377.8	38.55	1.080

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

Direct Shear Test for Soil Sample



Shear Stress = 1.080 Kg/Cm2

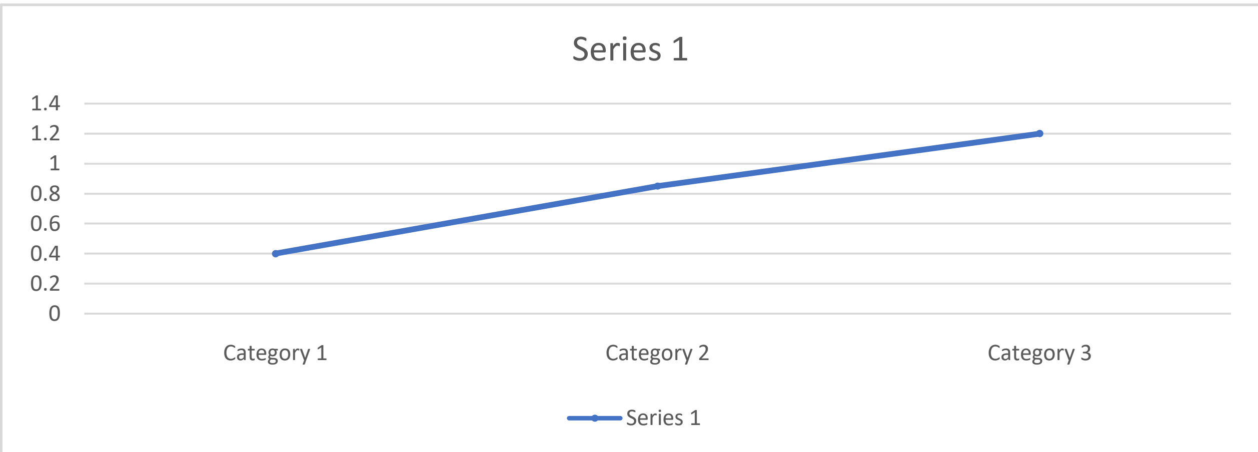
Shear Strength for Soil Sample with 0.0% Reinforcement

Volume of Shear Box	90 cm3
Maximum dry density of Soil	1.76%
Optimum moisture content of soil	14%
Weight of the soil to be filled in the shear box	176.4 gms
Weight of water to be added	30 gms

0.05% REINFORCEMENT SOIL SAMPLE WITH POLYPROPYLENE

Sample No	Normal stress (Kg/Cm2)	Proving ring reading	Shear load (n)	Shear load (kg)	Shear stress (kg/cm2)
1	0.5	28	140	14.28	0.400
2	1.0	57	29	30.30	0.850
3	1.5	82	420	42.80	1.200

Direct Shear Test for Soil Sample with 0.05% Reinforcement



Shear Stress = 1.2 Kg/Cm2

Shear Strength for Soil Sample with 0.05% Reinforcement

ISSN:2394-3386

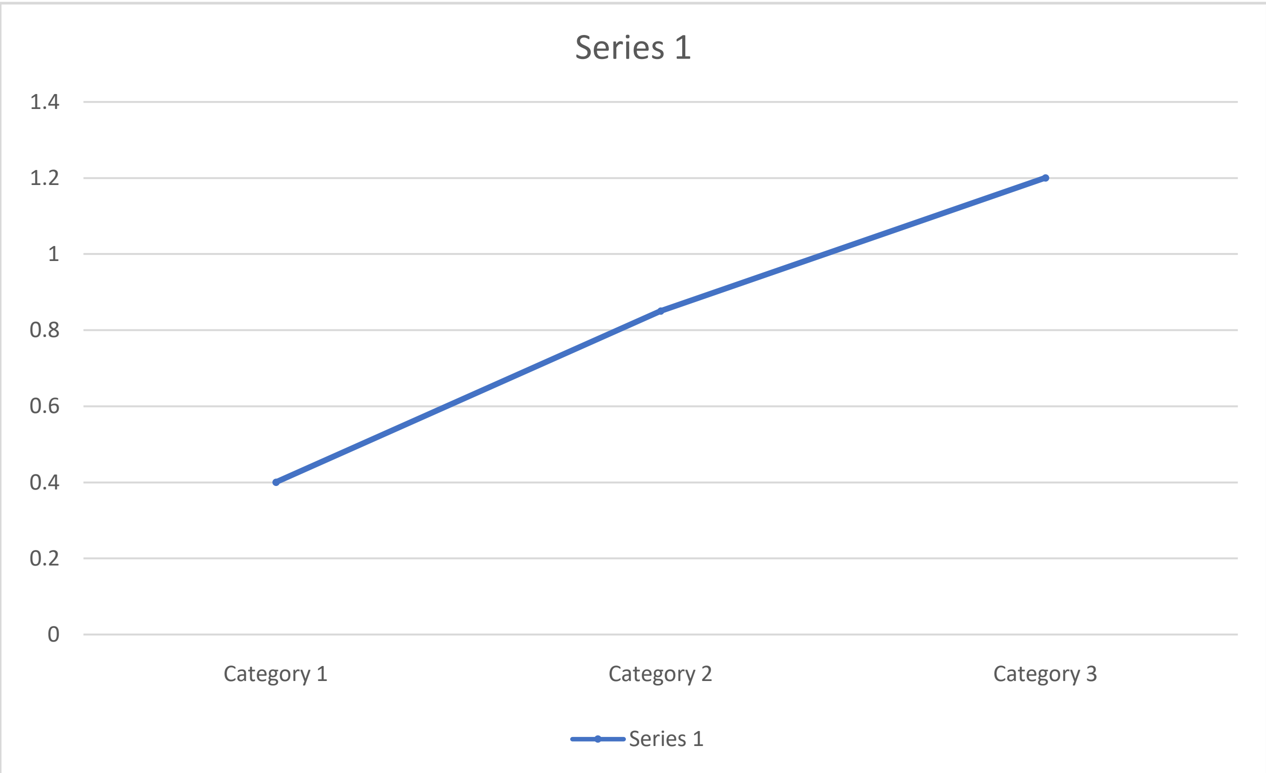
International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

Volume of Shear Box	90 cm3
Maximum dry density of Soil	1.76%
Optimum moisture content of soil	14%
Weight of the soil to be filled in the shear box	176.4 gms
Weight of water to be added	30 gms

0.15% REINFORCEMENT SOIL SAMPLE WITH POLYPROPYLENE

Sample No	Normal stress (Kg/Cm2)	Proving ring reading	Shear load (n)	Shear load (kg)	Shear stress (kg/cm2)
1	0.5	28	143	14.63	0.410
2	1.0	64	314.8	32.13	0.900
3	1.5	86	446.8	45.60	1.280

Direct Shear Test for Soil Sample with 0.15% Reinforcement



Shear Stress = 1.280 Kg/Cm2

Shear Strength for soil sample with 0.015% Reinforcement

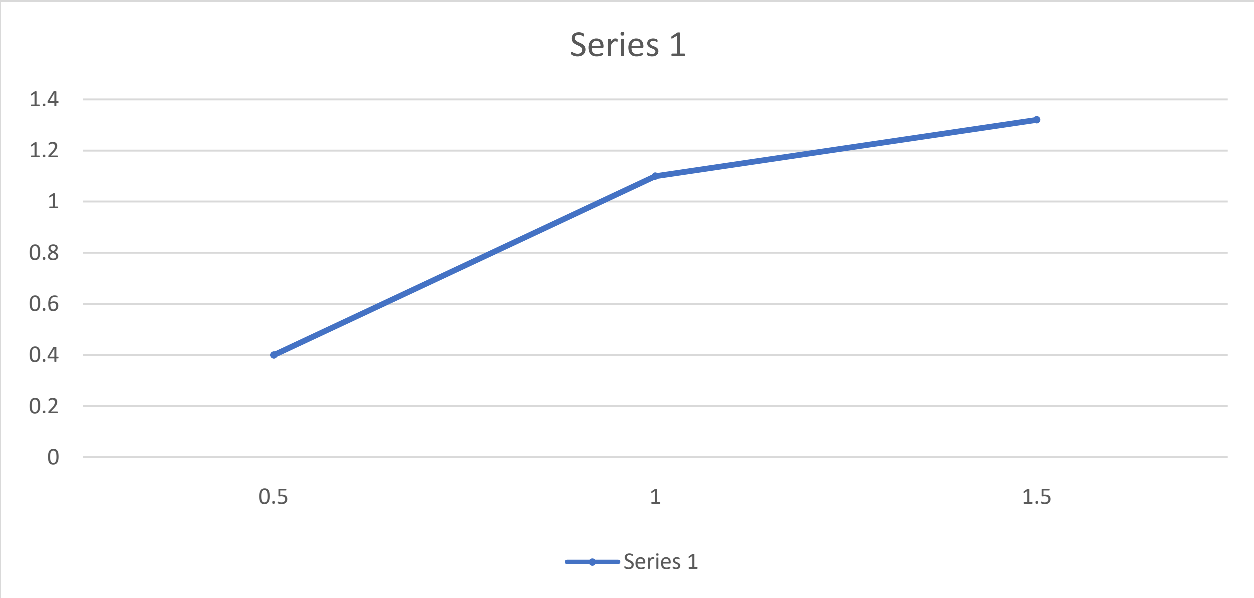
Volume of Shear Box	90 cm3
Maximum dry density of Soil	1.76%
Optimum moisture content of soil	14%
Weight of the soil to be filled in the shear box	176.4 gms
Weight of water to be added	30 gms

International Journal of Engineering Technology Science and Research
IJETSR
www.ijetsr.com
ISSN 2394 – 3386
Volume 4, Issue 9
September 2017

0.25% REINFORCEMENT SOIL SAMPLE WITH POLYPROPYLENE

Sample No	Normal stress (Kg/Cm2)	Proving ring reading	Shear load (n)	Shear load (kg)	Shear stress (kg/cm2)
1	0.5	30	147	15	0.42
2	1.0	70	384.16	39.2	1.1
3	1.5	88	461.58	47.1	1.32

Direct Shear Test for Soil Sample with 0.25% Reinforcement

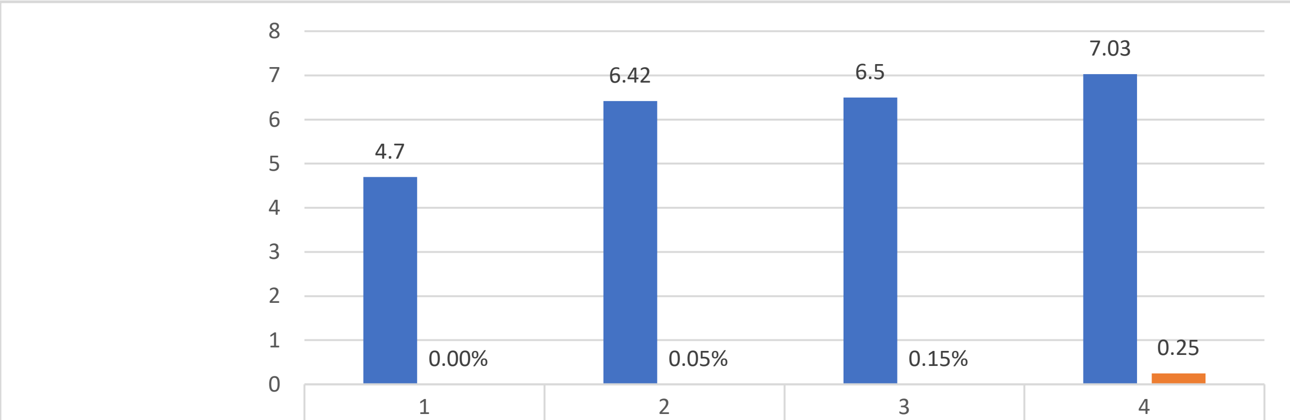


Shear Stress = 1.32 Kg/Cm2

Shear Strength for soil sample with 0.025% Reinforcement

DISCUSSIONS

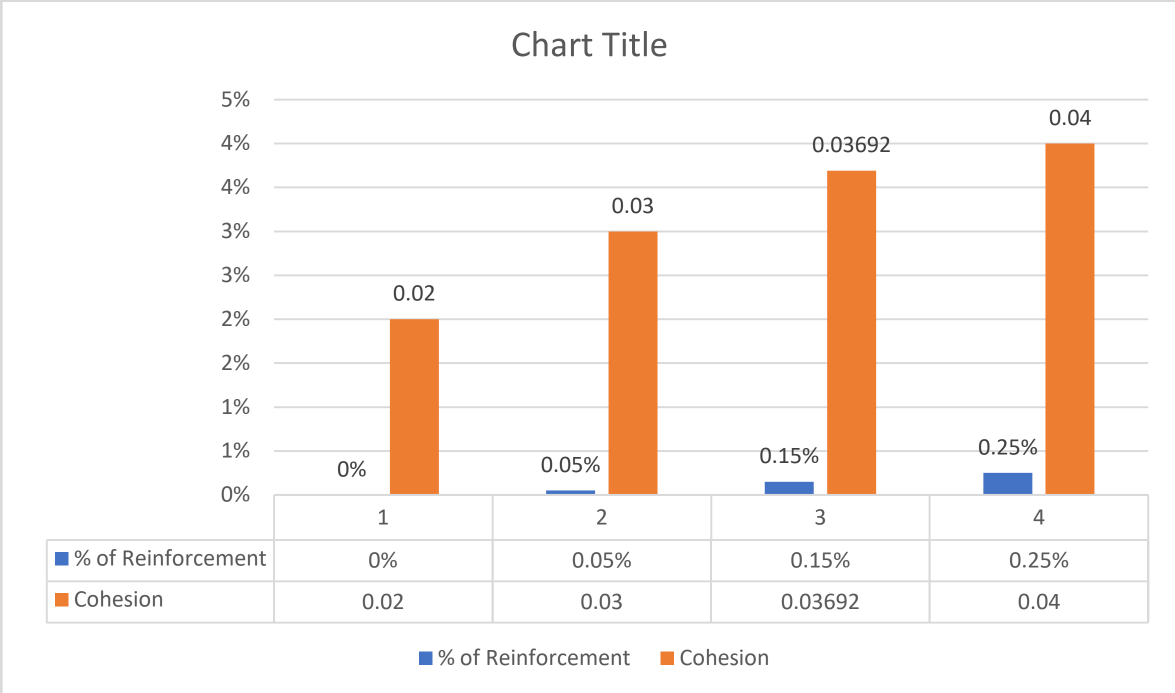
THE RELEATIONSHIP BETWEEN THE UCS AND FIBER CONTENT



	1	2	3	4
STRESS	4.7	6.42	6.5	7.03
% OF REINFORCEMENT	0.00%	0.05%	0.15%	0.25

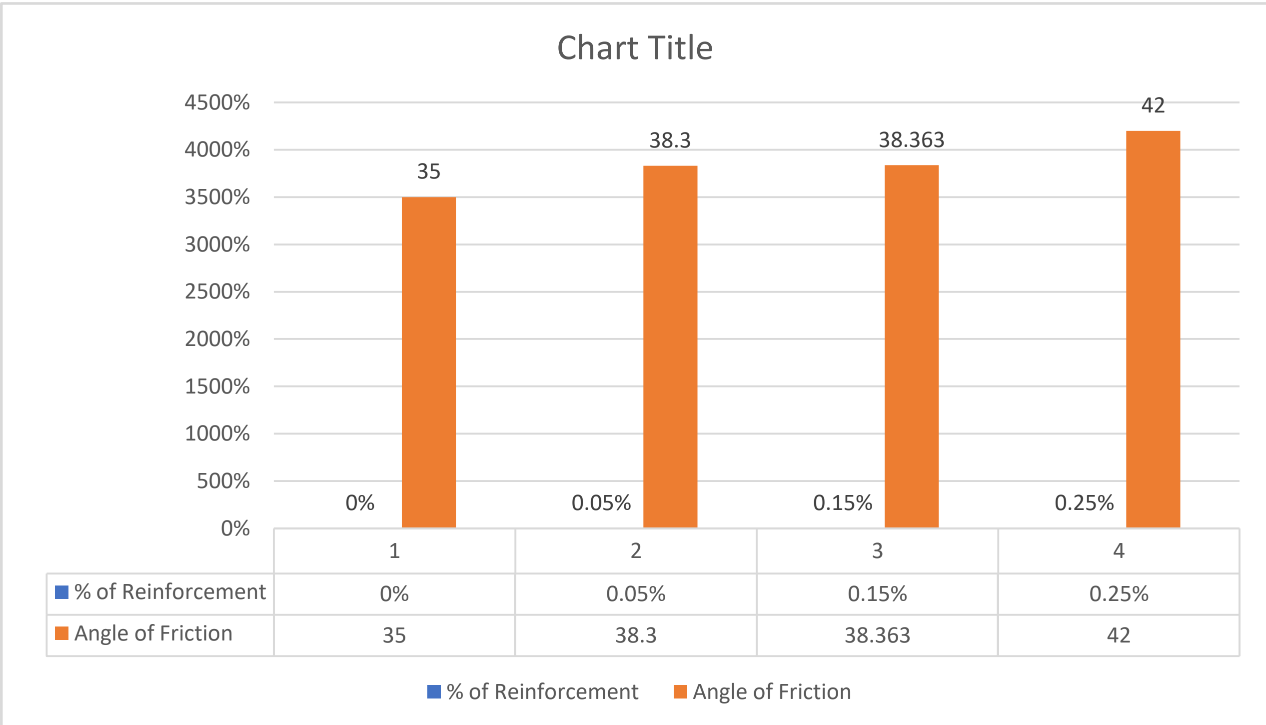
The Relationship between the UCS and Fiber constant

THE RELEATIONSHIP BETWEEN COHESION AND FIBER CONSTANT



The Relationship between the Cohesion and Fiber content

THE RELATIONSHIP BETWEEN THE ANGLE OF FRICTION AND FIBER CONTENT



The Relationship between angle of friction and % of reinforcement

INFERENCES

Inferences from Direct Shear Test for Soil Sample

- Cohesion value increases from 0.02kg/cm2 to 0.04kg/cm2, a net 100.0%
- The increment graph for cohesion shows a gradual decline in slope.
- The angle of internal friction increases from 35 to 42 degrees, a net 20.0%
- The incremental graph for φ shows a variation in shape alternative raise and fall
- The incremental in shear strength of soil due to reinforcement is substantial.

Inferences from UCS Test for Soil Sample

- UCS value increases from 4.7kg/cm2 to 7.03kg/cm2, a net 50%.
- The shape of incremental graph varies with alternative raise and fall.

CONCLUSION

On the basis of present experimental study, the following conclusions are drawn,

- Based on direct shear test on soil sample, with fiber reinforcement of 0.05%,0.15% and 0.25%, the increase in cohesion was found to be 50%, 34.6%, and 22.4%, 3.9% and 6.1% respectively. The increase in the internal angle of friction (φ) was found to be 10%, 3.9% and 6.1% respectively.
- Since the net increase in the value of c and φ were observed to be 100%, from 0.02kg/cm2 to 0.04kg/cm2 and 20%, from 35 to 42 degrees net increment respectively, for such soil, randomly distributed polypropylene fiber reinforcement is recommended.
- The result from the UCS test for soil sample are also similar, for reinforcement of 0.05%, 0.15% and 0.25%, the increase in UCS from the initial value are 35.31%, 1.1% and 8.8% respectively. This increment is substantial and applying it for soil sample is effective.
- Overall it can be concluded that fiber reinforced soil can be considered to be good ground improvement technique specially in engineering projects on weak soil where it can act as a substitute to deep/raft foundations, reducing the cost as well as energy.

REFERENCES

1. S. A. Naeini and S. M. Sadjadi, (2008)," Effect of Waste Polymer Materials on Shear Strength of Unsaturated Clays", EJGE Journal, Vol 13, Bund k,(1-12).
2. Yetimoglu, T., Inanir, M., Inanir, O.E., 2005. A study on bearing capacity of randomly distributed fiber-reinforced sand fills overlying soft clay. Geotextiles and Geomembranes 23 (2), 174–183.
3. Chaosheng Tang, Bin Shi, Wei Gao, Fengjun Chen, Yi Cai, 2006. Strength and mechanical behavior of short polypropylene fiber reinforced and cement stabilized clayey soil. Geotextiles and Geomembranes 25 (2007) 194–202.
4. Mahmood R. Abdi, Ali Parsapajouh, and Mohammad A. Arjomand,(2008)," Effects of Random Fiber Inclusion on Consolidation, Hydraulic Conductivity, Swelling, Shrinkage Limit and Desiccation Cracking of Clays", International Journal of Civil Engineering, Vol. 6, No. 4, (284-292).
5. Consoli, N. C., Prietto, P. D. M. and Ulbrich, L. A. (1999). ''The behavior of a fibre reinforced cemented soil.'' Ground Improvement, London, 3(1), 21–30.
6. IS 2720 – part (xiii) 1980-87
7. The need for soil stabilization, April 9, 2011 by Ana [online] Available at: <http://www.contracostalandscaping.com/the-need-for-soil-stabilization/>
8. Methods of soil stabilization, December 24, 2010 [online] Available at: < http://www.engineeringtraining.tpub.com/14070/css/14070_424.htm >
9. Prof. Krishna Reddy, UIC, 2008, Engineering Properties of Soils Based on Laboratory Testing.
10. Understanding the Basics of Soil Stabilization: An Overview of Materials and Techniques [online] Available at: <http://www.cat.com >
11. Punmia B.C. 2007, "Soil Mechanics & Foundations" Laxmi Publications

12. Yadav Parit, Meena Kuldeep Kumar, (2011)" A comparative study in soil plasticity of Hall area and lecture complex area of NIT Rourkela" B.tech thesis, NIT,Rourkela.
13. IS: 2720(Part-2), 1973 Methods of Test for Soils. Determination of water content.
14. IS 2720(III/SEC-I): 1980 Methods of Test for Soils. Determination of specific gravity.
15. IS 2720(VII):1980 Methods of Test for Soils. Determination of water content dry density relation using light compaction.
16. IS 2720(XIII):1986 Methods of Test for Soils, direct shear test
17. IS 2720(X):1991 Methods of Test for Soils. Determination of unconfined compression test.
18. IS 2720(IV):1985 Methods of Test for Soils. Determination of grain size analysis.