A Study on Effect of Addition of Paper Waste on Shear Behavior of Cohesive Soil

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Abstract - *Waste paper impart huge environmental problems. Scavenge paper also poses clogging of drainage conduits and as such often observed rainwater detention in cities and towns. Ministry of Environment and Forest (MoEF) and Central Pollution Control Board (CPCB) inducted rules for paper waste management and recommended also possible recycling of waste as far as possible. For a sustainable resource management practice, paper wastes are being recycled in many ways. A common problem with recycling papers is that they are often made up of more than one kind of material or some sort of chemicals added to the papers (a composite) to give added strength. The above characteristics are helpful for using the waste materials in poor grade soil to enhance the geotechnical properties of soil. Paper wastes are similar to the roots of trees and vegetation which provide an excellent ingredient to improve the soils and the stability of natural slopes. One of the main advantages of using paper is the maintenance of strength isotropy and the absence of potential places of weakness that can develop parallel to oriented reinforcement. The objective of this project is to identify and assess the use of paper to enhance the shear strength of cohesive soils. This study includes identifying type of paper to be used, determining properties of soil and analyzing improvements in the shear behavior of cohesive soils. Clays are naturally occurring materials composed primarily of fine grained minerals, which shows property through a variable range of water content and which can be hardened when dried or fired. Generally, soft clay soil has low bearing capacity and large settlements that take place for a long period of time. Clayey soils are synonymous to problematic soils in Civil Engineering construction because of their swelling characteristics. Though many forms of stabilization exists but the challenge for civil engineering community in the near future will be to realize the projects in harmony with the concept of sustainable development and that involves the use of high performance materials produced at reasonable costs with the lowest possible environmental impact. In the view of global sustainable development and emphasis on environmental conditions, it is imperative that supplementary stabilizing material like paper wastes, which is also renewable are to be used. The soil stabilization is an effective and reliable technique for improving strength and stability of soils. We have investigated the influence of randomly oriented paper strips on highly compressible clayey soils. The paper selected for this purpose is the waste of spirals which is in circular shape which is 4mm diameter, the purpose of selecting this is to get uniformity in size distribution and thus can be effectively used for this experiment purpose*

Key Words: Shear Strength, Cohesive soils, Mohr's Circle, Paper pieces, Sustainability.

1. INTRODUCTION

Cohesive soil is a fine-grained natural rock or soil material that combines one or more clay minerals with traces of metal oxides and organic matter. Geologic clay deposits are mostly composed of phyllosilicate minerals containing variable amounts of water trapped in the mineral structure. Clay is paper due to that water content, becoming hard, brittle and non–paper upon drying or firing.

1.1 Shear strength of cohesive soil

Shear strength is a term used in mechanics to describe the magnitude of the shear stress that a soil can sustain. The shear resistance of soil is a result of friction and interlocking of particles, and possibly cementation or bonding at particle contacts. Due to interlocking, particulate material may expand or contract in volume as it is subject to trains. If soil expands its volume, the density of particles will decrease and the Strength will decrease; in this case, the peak strength would be followed by a reduction of shear stress. The stress-strain relationship levels off when the material stops expanding or contracting, and when inter particle bonds are broken. The theoretical state at which the shear stress and density remain constant, while the shear strain increases may be called the critical state, steady state, or residual strength.

1.2 Papers with soil

Paper is generally made with trees and vegetation which provide an excellent ingredient to improve the soils and the stability of natural slopes. One of the main advantages of using paper is the maintenance of strength isotropy and the absence of potential places of weakness that can develop parallel to oriented reinforcement. A paper based product typically contains 90–99% cellulose fibers which are the primary structural element and the most important component influencing end use properties. A network of self-bonding cellulose fibers within network structure affects chemical and physical characteristics of the paper products. Thus, paper is made mostly out of organic compounds: that is carbon, hydrogen and oxygen (C, H & O). Paper also contains non organic materials to improve its properties. These may be chalk ($CaCO3$) and kaolin clay ($Al2Si2O5(OH)4$). Titanium oxide ($TiO2$) is also commonly used in paper for bleaching

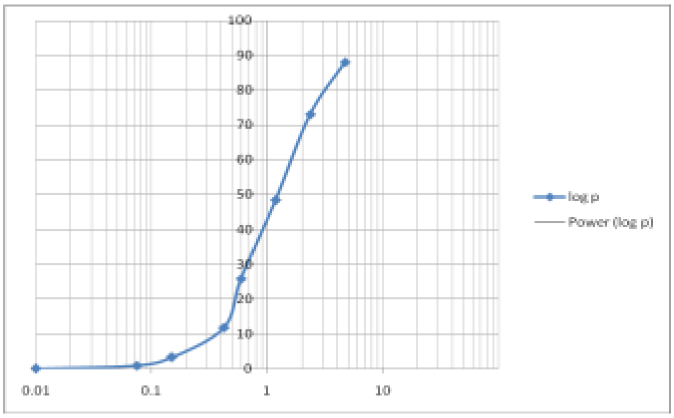
1.3 Material(Paper) used

In order to get uniform paper pieces we have selected the waste that comes from punching of papers whose dimensions can be given as 4mm in diameter and thickness is approximately 0.1mm. The quantity used here is 2.5% and 5% by weight of soil

2. EXPERIMENTAL INVESTIGATION

2.1 SIEVE ANALYSIS

Sieve analysis is a procedure used to assess the particle size distribution of granular material. It helps to classify the soil into coarse aggregates and fine aggregates and also gives us clear picture in concluding the soil as whether well graded or poorly graded. The standard IS:2386(Part I)-1963 code suggests to use different sizes of sieves and then pass aggregates through them and collect different sized particles left over in. The percentage of finer is calculated and tabulated. A curve was plotted on semi log graph representing % finer on arithmetic scale and sieve sizes on log scale



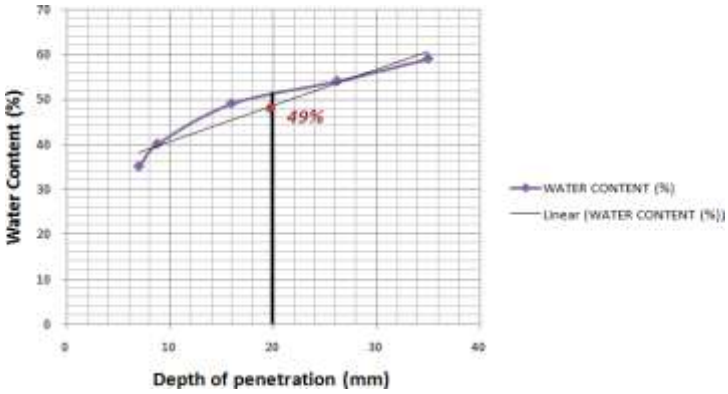
Graph: 1 Sieve analysis

Table: 1 Sieve analysis

S.NO	SEIVE SIZE	WEIGHT	%WEIGHT	CUMULATIVE WEIGHT	%FINER
1	4.75	119.5	11.95	11.95	88.05
2	2.36	149.5	14.95	26.9	73.1
3	1.18	247	24.7	51.6	48.4
4	0.6	226	22.6	74.2	25.8
5	0.425	140	16	88.2	11.8
6	0.15	85.5	8.55	96.75	3.25
7	0.075	14.5	1.45	98.2	0.8
8	0	15.5	1.55	99.75	0.25

2.2 LIQUID LIMIT TEST

Liquid limit is the water content at which the soil changes from liquid state to paper state. At liquid limit the soil is practically like a liquid but possess a small shearing strength. The stronger the surface charge and thinner the particle, the greater will be the amount of the adsorbed water and therefore, the higher will be the liquid limit. As per IS: 2720-(part-V) the liquid limit of soil was determined by “cone penetration apparatus”



Graph: 2 Liquid limit

Table: 2 Liquid limit

S.NO	DEPTH OF CONE PENETRATION	WATER CONTENT %
1	7	35
2	8.8	40
3	26.2	54
4	20	49

2.3 PLASTIC LIMIT TEST

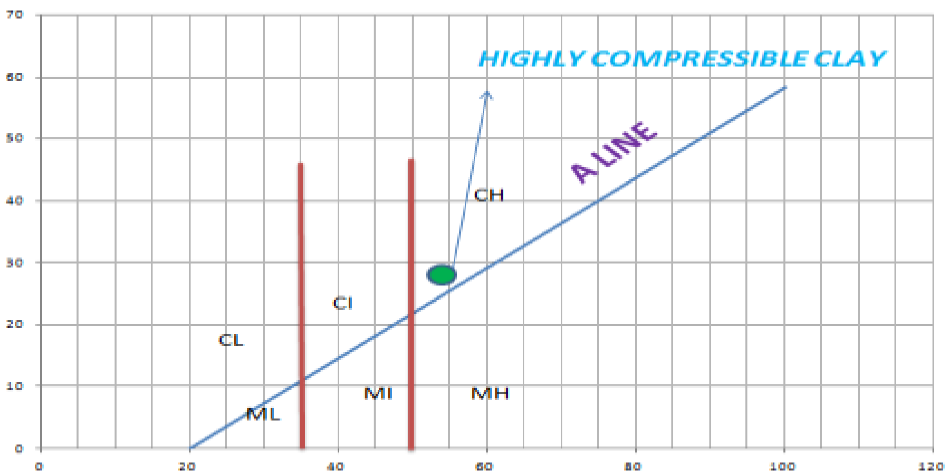
Paper limit is the water content below which it stops behaving as paper material. It begins to crumble when rolled into a thread of 3mm diameter. At this state the soil losses its paternity and enters semi solid state.

Table: 3 Plastic limits

S.NO	WET WEIGHT (gm)	OVEN DRIED (gm)
1	1.26	1
2	1.27	1

2.4 CLASSIFICATION OF SOIL

A PLASTICITY chart is used to differentiate the plasticity and organic characteristics of the fine grained soils based on liquid limit (LL) and plasticity index (PI) of the soils. Once the liquid limit and the plastic limit were known, the plasticity index of the soil was calculated as below.



Graph: 3 Plasticity chart

Table: 4 Specific gravity

S.NO	TEST 1 (g)	TEST 2 (g)
WEIGHT OF BOTTLE	26	26
WEIGHT OF SAMPLE W2	43.5	43
WEIGHT OF BOTTLE + KEROSENE W3	78.5	78.5
WEIGHT OF KEROSENE W4	66.5	66.5
WEIGHT OF WATER W5	78	78
SPECIFIC GRAVITY OF KEROSENE	0.8	0.8
SPECIFIC GRAVITY OF soil	2.63	2.63

2.5 SPECIFIC GRAVITY

Specific gravity of solid particles G, is defined as the ratio of the mass of a given volume the solids to the mass of an equal volume of water. IS: 2720-part III deals with the method of test for determination of specific gravity of soils, which is useful in finding out unit weight of moist soils which in turn necessary to find out engineering properties such as settlement and stability problems.

2.5 UNCONFINED COMPRESSION TEST (IS 2720-PART 10:1991)

This standard (part10) describes the method for determining the unconfined compressive strength of clayey soil, undisturbed, remolded or compacted, using controlled rate of strain.

Terminology: For the purpose of this standard, the following terms are repeatedly used. Unconfined compressive strength qu, it is the load per unit area at which an unconfined cylindrical specimen will fail under axial compression.

NOTE- If the axial compression force per unit area has not reached a maximum value even at 20% of axial strain, qu shall be taken as the value attained at 20% axial strain.

Mohr's circle It helps us to determine the strength, failure surface and the angle of internal friction. As specified testing is done on cohesive soils, angle of internal friction will always be zero i.e. ø = 0

PREPATION OF SAMPLE

Specimen shall be cylindrical and have a 3.8 cm diameter and 8 cm height. About 160 gm of soil sample was taken and was made free from lumps and mixed with suitable water content. A mould was taken and specimen mould was taken and little portion of sample was kept in the mould and compacted for about 25times using glass tamping rod. Grease should be applied thoroughly to the mould before molding and removing the excess soil and taking the prepared sample from mould

Figure: 1 Soil with paper pieces

Figure: 2 prepared mould

Figure: 3 Unconfined compression test

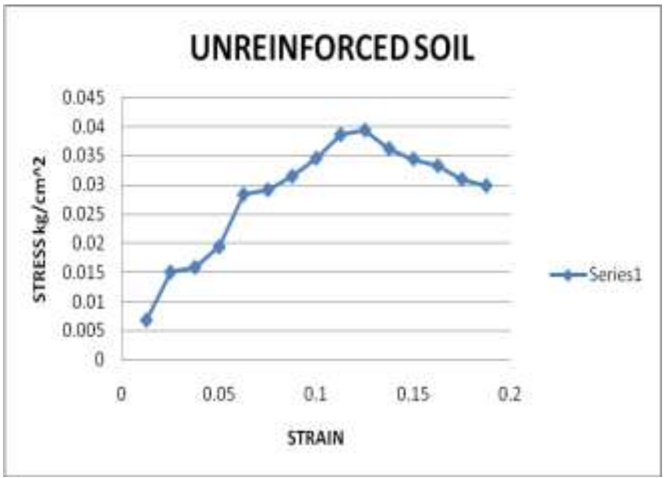
TESTING OF SAMPLES

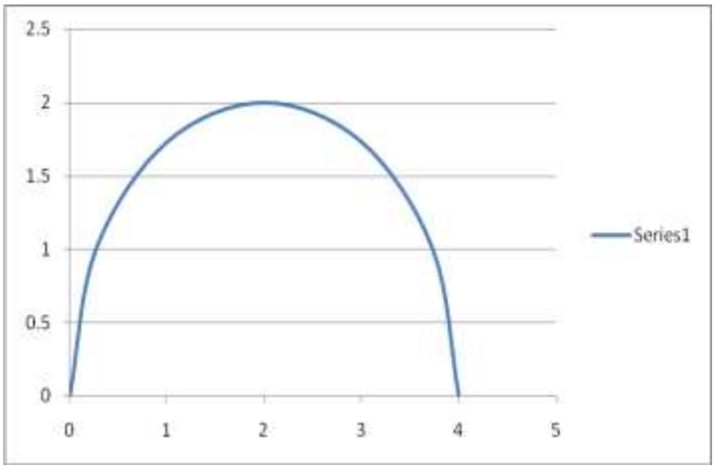
The prepared sample was placed between in between two conical seating and fixed with load or nut bolt arrangement so that the specimen should not move. The readings on dial gauge and proving are set to zero and set up is ready

Increase the load from testing machine and for every dial gauge of 50 measures proving reading and tabulate in sheet. Plot the graph for stress strain curve

Sample: 1

Unreinforced sample

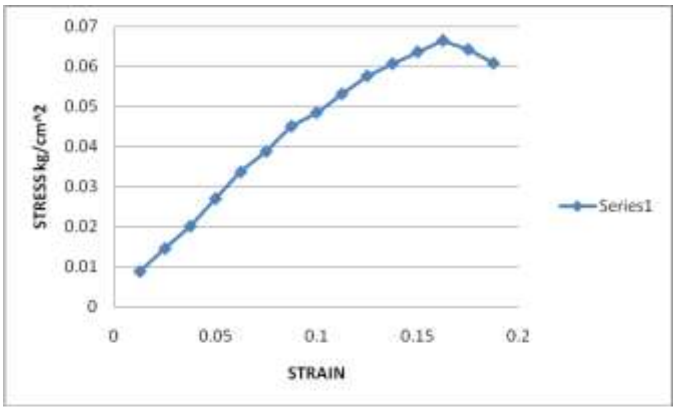


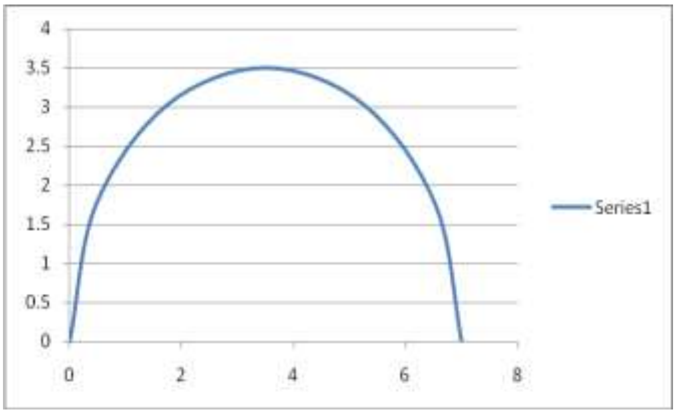


Graph: 3 stress strain curve for unreinforced **Graph: 4 Mohr's circle for unreinforced**

Sample: 2

Reinforced with 2.5% of paper pieces

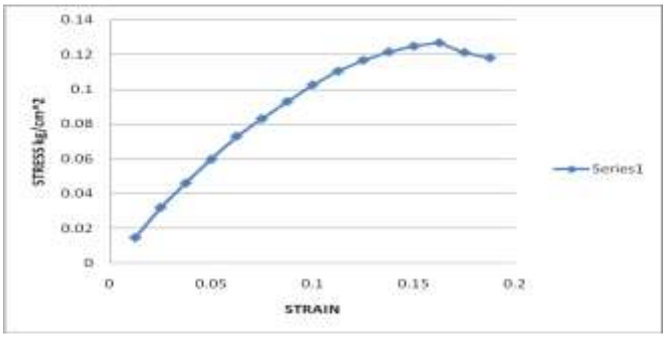




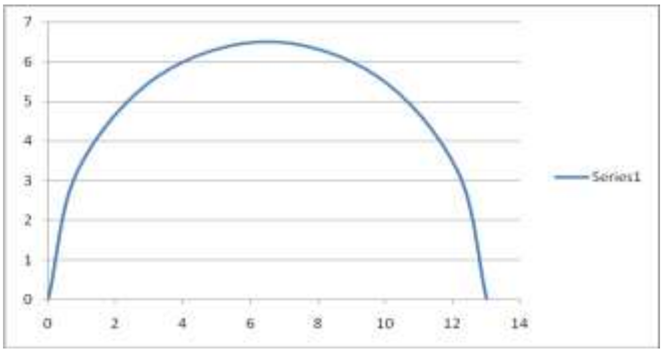
Graph: 5 stress strain curve for 2.5% **Graph: 6 Mohr's circle for reinforced with 2.5%**

Sample: 3

Reinforced with 5% of paper pieces



Graph: 7 stress strain curve for 5%



Graph: 8 Mohr's circle for 5%

UNREINFORCED SOIL SAMPLE							
sl no.	Dial gauge	Deformation Δl	ε = Δl/l	proving ring reading (P)	Load = P*CF	Ac=Ao/1-ε	Stress = load/Ac
1	50	0.1	0.0125	0.46	0.0782	11.483	0.00680
2	100	0.2	0.025	1.03	0.1751	11.630	0.01505
3	150	0.3	0.0375	1.1	0.187	11.781	0.01587
4	200	0.4	0.0500	1.36	0.2312	11.936	0.01936
5	250	0.5	0.0625	2.016	0.34272	12.096	0.02833
6	300	0.6	0.0750	2.1	0.357	12.259	0.02912
7	350	0.7	0.0875	2.3	0.391	12.427	0.03146
8	400	0.8	0.1011	2.56	0.4352	12.601	0.03453
9	450	0.9	0.1125	2.9	0.493	12.777	0.03858
10	500	1	0.1250	3	0.51	12.960	0.03935

SOIL REINFORCED WITH 2.5%							
sl no.	Dial gauge	Deformation Δl	ε= Δl/l	Proving ring reading (P)	Load = P*CF	Ac=Ao/1-ε	Stress = load/Ac
1	50	0.1	0.0125	0.6	0.102	11.483	0.00888
2	100	0.2	0.025	1	0.17	11.630	0.01461
3	150	0.3	0.0375	1.4	0.238	11.781	0.02020
4	200	0.4	0.05	1.9	0.323	11.936	0.02705
5	250	0.5	0.0625	2.4	0.408	12.096	0.03373
6	300	0.6	0.075	2.8	0.476	12.259	0.03880
7	350	0.7	0.0875	3.3	0.561	12.427	0.04514
8	400	0.8	0.1	3.6	0.612	12.601	0.04857
9	450	0.9	0.1125	4	0.68	12.777	0.05321
10	500	1	0.125	4.4	0.748	12.960	0.05771

BLACK COTTON SOIL - REINFORCED WITH 5%							
sl no.	Dial gauge	Deformation Δl	ε= Δl/l	proving ring reading (P)	Load = P*CF	Ac=Ao/1-ε	Stress = load/Ac
1	50	0.1	0.0125	1	0.17	11.483	0.01480
2	100	0.2	0.025	2.2	0.374	11.630	0.03215
3	150	0.3	0.0375	3.2	0.544	11.781	0.04617
4	200	0.4	0.05	4.2	0.714	11.936	0.05981
5	250	0.5	0.0625	5.2	0.884	12.096	0.07308
6	300	0.6	0.075	6	1.02	12.259	0.08320
7	350	0.7	0.0875	6.8	1.156	12.456	0.09302
8	400	0.8	0.1	7.6	1.292	12.602	0.10253
9	450	0.9	0.1125	8.3	1.411	12.777	0.11042
10	500	1	0.125	8.9	1.513	12.960	0.11677

3. RESULTS

1. Sieve analysis: The curved obtained on joining the points is S-shaped which shows that the soil is well graded.

2. Liquid limit: The liquid limit for given soil sample is 49%

3. Plastic limit: The plastic limit of given soil sample is 20.63%.

4. Soil classification: From plasticity chart, soil is classified as highly compressible clay.

5. Unconfined compression test

a) Unreinforced sample

1) Max. Stress = 0.039 kg/cm^2 or 3.85 kPa

2) Shear strength = 0.0195 kg/cm^ or 1.925 kPa

b) 2.5% reinforced

1) Max. Stress =0.066 kg/cm^2 or 6.52 kPa

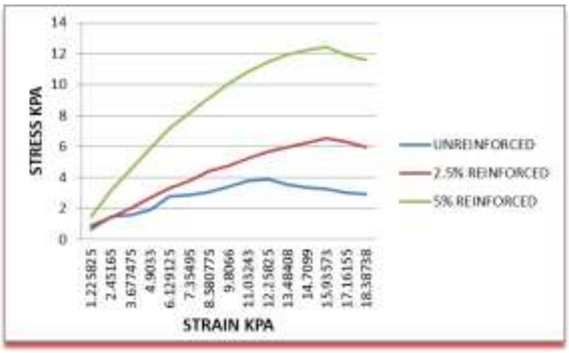
2) Shear strength = 0.033 kg/cm^2 or 3.26 kPa

c) 5% reinforced

1) Max. Stress =0.126 kg/cm^2 or 12.43 kPa

2) Shear strength = 0.063 kg/cm^2 or 6.215 kPa.

4. COMPARATIVE ANALYSIS



Graph: 9 stress strain curves **Graph: 10 Mohr's circles**

5. CONCLUSIONS

The above comparative figure shows that there is drastic increase in shear strength of soil which is calculated when soil is reinforced with 5%. However, by just increasing the paper content the strength can't be increased and further samples of different percentages should be carried out

Therefore the percentage increased by adding 5% of paper is 222.85%

Hence it could be inferred from the obtained conclusions that paper wastes can be used to effectively increase the strength and stability of the soil, promoting sustainable living.

SCOPE FOR FUTURE STUDY

1. This project only dealt with 4mm as the size of the paper pieces for all kinds of tests. With change in aspect ratio there is a possibility for the shear strength and stress to vary.
2. The soil considered here for tests are mixed with pieces of 4mm. With varying sizes of different sizes and shapes, tests can be conducted and compared.
3. The effect of paper on other engineering properties of the soil like permeability, CBR values, compaction characteristics etc can also be studied.

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