STRENGTH DEVELOPMENT OF SOFT SOIL STABILIZED WITH WASTE PAPER SLUDGE

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ABSTRACT

The main objective of this study is to investigate the use of waste materials in geotechnical applications and to evaluate the effects of waste paper sludge on strength development of soft soil. This review discusses the effect of waste paper sludge on stabilized soils. In this paper, attempts are made to utilize the same for the soil improvement. The application of Waste Paper Sludge (WPS) will be investigated in this study by conducting laboratory tests, compaction and unconfined compressive strength. Soil with 2% and 5% WPS have an optimum moisture content more closed to OMC of clay soil alone. The addition of WPS has increased the strength at 5% and it was found to be a constant and optimum value of strength to soil. In general it was found that WPS is a suitable waste material for strengthening soft soil. The beneficial reuse of the paper sludge also saved landfill space.

Keywords: *Paper Sludge, Soil stabilization, Compressive strength, Compaction*

I. INTRODUCTION

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. Paper mill sludge is a major environmental problem for the paper industry. The material is a by-product of the de-inking and re-pulping of paper. The total quantity of paper mill sludge produced in annually is large quantity. The main recycling and disposal routes for paper sludge are land-spreading as agricultural fertilizer, incineration in plants at the paper mill, producing paper sludge ash or disposal to landfill. The scope for landfill spreading is limited. Usage of paper increased to a great extent now days, results in large production of waste paper sludge (WPS). A large percentage of WPS produced are used for land filling and it run out of the storage space. There is therefore a growing need to find alternative uses of Waste Paper Sludge. This study explored the possibility of utilizing WPS for ground improvement schemes in geotechnical engineering applications.

1.1 Principles of soil stabilization

The principles of soil stabilization include:

- 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.

1.2 Components of stabilization

Soil stabilization is the process of improving the engineering properties of weak soil and thus making it more stable. The chief properties of a soil with which the construction engineer is concerned are: volume stability, strength, permeability, and durability. Soil stabilization involves the use of stabilizing agents (binder materials) in weak soils to improve its geotechnical properties such as compressibility, strength, permeability and durability. The components of stabilization technology include soils and or soil minerals and stabilizing agent or binders.

1.2.1 Soil

Most of stabilization has to be undertaken in soft soils (silty, clayey peat or organic soils) in order to achieve desirable engineering properties. A clay soil compared to others has a large surface area due to flat and elongated particle shapes.

1.2.2 Waste Paper Sludge (WPS)

Waste Paper Sludge (WPS) is a waste material collected from the Paper Industry. WPS becomes a new innovation material that can be used as material for soil stabilizing agent. Recycling and reuse of paper sludge is a topic of international interest in the past few decades.

The paper sludge for the study was collected from a recycled paper manufacturing company. The sludge for the soil stabilization behaves a clay-like material consisting of short fibers, ink and other impurities. During the paper recycling process, waste papers were collected and de-inked prior to recovery of the fiber. The sludge in the study will be the fiber sludge generated from the deinking process, which contains fibers too short to be converted to a finished paper product. The sludge will be partially dewatered before discharge and the texture will soft and limp. Since the plant operated at 24 hours a day, 7 days a week, the sludge generates continuously throughout the operating year. Freshly collected sludge samples will be essentially odorless and there will not be any distinct odors. It consists of unusable short fibers, inks and dyes, clay, glues and other residue, along with any chemicals used in the recovery process. Fig.1 shows waste paper sludge at dried condition.

Fig.1 Waste Paper sludge (WPS)

II. NEED FOR THE STUDY

The disposal of industrial wastes is a major problem nowadays. Plants with on-site landfills are running out of storage space. The Sludge from the paper mills are produced in large quantities, due to the large usage of paper. First, they are typically less costly due to the fact that they are a waste product that already needs to be disposed of. Second, finding alternative uses for these materials keeps them out of landfills, ultimately saving already depleting landfill space.

III. OBJECTIVES OF PRESENT STUDY

- To study the engineering behaviour and geotechnical properties of WPS with various proportions of the paper sludge and soil
- To determine an optimum dose of the stabilizing agents

IV. METHODOLOGY

The methodology adopted to achieve the objective of the project is detailed as follows. The properties of the soil get modified with the addition of stabilisers. Experiments have to be done to determine the physical properties of the soil and the change in the geotechnical properties of the soil with the addition of this amendment.

4.1 Materials

The materials used in this study were clayey soil and Waste Paper Sludge. The soil for the experimental investigation was collected from Kannadikadavu, Kundannoor of Ernakulam district. The soil for the investigation was silty clay with a moisture content of 70%. The waste paper sludge sample was collected in plastic containers from the sludge drying bed of the Hindustan newsprint plant, Vellore, Kottayam. The moisture content normally present in paper sludge may vary from 60-120%. Inorganic components are mainly kaolinite and calcium carbonate. Geotechnical properties of WPS were conducted. Air dried clay sample for the investigation is shown in Fig.2.

Fig.2 Air dried clay sample

4.2 Basic Properties of Clayey Soil

Most of stabilization has to be undertaken in soft soils in order to achieve desirable engineering properties. The following basic properties of soil sample were investigated. The results of the experiments conducted to determine the basic properties of soil are tabulated in Table.1.

Table .1 Properties of Clayey Soil

Properties	Value
Silt (%)	74%
Clay (%)	26%
(a)Liquid Limit (%)	60%
(b)Plastic Limit (%)	31%
(c) Shrinkage limit (%)	23%
(e)Plasticity Index (%)	30%
Specific Gravity	2.59
Maximum Dry Unit Weight (kN/m^3)	16.3
Optimum Moisture Content (%)	22
Unconfined compressive Strength (kN/m^2)	316.4
Cohesion (kN/m^2)	158.2

4.3 Properties of Waste Paper Sludge

The sludge sample was taken at their natural water content and air dried at standard temperature. Then it is grinded to smaller size so that it passed through 4.75mm IS sieve. Some properties of paper sludge were analyzed, including water content, pH value, specific gravity etc in dried sludge. The properties of the Waste Paper Sludge used for the study are given in the Table.2 below.

Table .2 Properties of waste paper sludge

1	Specific gravity	1.33
3	pH	7.04
4	Water content (%)	60-120
5	Φ	13.5^0
6	c	0.17
7	Hydraulic conductivity (m/s)	1.1 x10^{-8}

4.4 Experimental Investigations

In the present study a series of experimental work was conducted to evaluate the strength of soft soil and various proportions of waste paper sludge and soft soil. The index as well as engineering properties have been evaluated. The experiments which were performed are compaction test and unconfined compression test. The results of various tests were discussed and compared. Soil stabilization is including as an accurate way to improve the soil strength, the implementation is based on laboratory testing. The experimental study involves standard Proctor's compaction test and unconfined compressive test. The compaction test was carried out on clay soil and soil with 2, 5,7,10,15,20,25 percent WPS by weight to study the compaction behaviour. Compaction tests were conducted to get the OMC and MDD of the mix of different proportions of soil and Waste Paper Sludge. Preparation of soil sample for proctor's compaction test was done as per IS code: 2720 (part – VIII), 1979.

Fig.3 Laboratory UCS Test Set Up

The unconfined compressive strength tests of the raw soils were performed on samples prepared at optimum moisture content and 90% of that corresponds to maximum dry density. Unconfined compression tests were performed to determine the stress-strain of soil treated with Waste Paper Sludge. A metallic mould 38 mm inner diameter × 76 mm long with detachable collars was used to prepare the specimens. For treated soil specimens, the waste paper sludge was added as a percentage of weight of dry soil.

V. RESULTS & DISCUSSIONS

5.1 Proctor compaction test (IS 2720: part – VIII, 1979)

The results have been summarized and presented in Fig.4. It can be seen that as the percentage of WPS added increases, the maximum dry density and optimum moisture content decrease and increase respectively, indicating the behavior of soft soil associated with the addition of stabilizer.

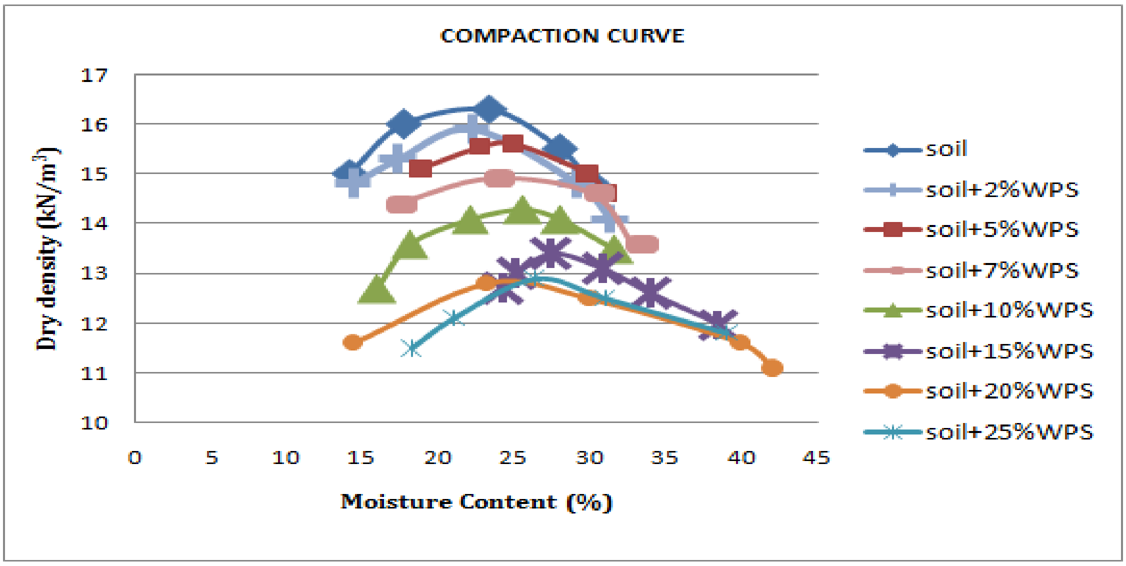

Fig.4 Variations in Compaction Curves

It can be seen from the graph that for all the seven percentages of WPS the value of optimum moisture content is slightly more than the optimum moisture content of soil without the addition of WPS and maximum dry density is less than the maximum dry density of soil without the addition of WPS. The optimum moisture content has increased and the maximum dry density has decreased continuously with addition of WPS. Addition of 2% WPS to soil exhibited the highest maximum dry density when compared to other percentages. The summary of the Standard Proctor test results of treated soils as compared with the raw soils is presented in the Table 5.1.

Table .3 Change In Compaction Characteristics Of Soil With WPS

Mixture	OMC %	γ_d (kN/m^3)
clay	22.0	16.30
clay+2%wps	22.2	15.90
clay+5%wps	23.5	15.61
clay+7%wps	24.0	14.90
clay+10%wps	25.5	14.30
clay+15%wps	27.0	13.40
clay+20%wps	24.5	12.90
clay+25%wps	26.5	12.90

The maximum percentage increase in optimum moisture content (OMC) is 22.7%. The maximum percentage decrease in dry density γd for the WPS-treated soil was observed to be 20.9%. Maximum dry density γd reached a constant value of 1.29 at 20%WPS and 25%WPS. It is clear from the table that effect of the WPS content shows a decrease on the density of the specimens. This is because of the low specific gravity of the WPS and the loose state of WPS. Whereas optimum moisture content of soils were found to be increased with the addition of WPS.

5.2 Unconfined Compressive Strength of Soil (IS 2720: Part X, 1991)

The variation of the UCS of the raw soils with varying proportion of Waste Paper Sludge at 0 day is presented in Fig.5.

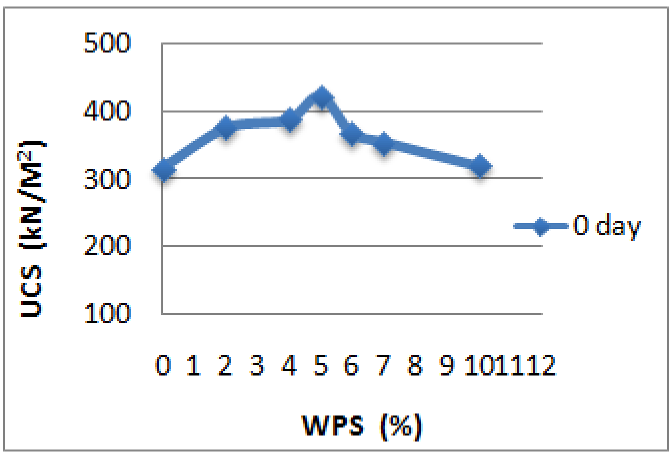

Fig.5 Variation of UCS with WPS (%) 0 days

Table .4 Unconfined Compressive Strength of WPS Treated With Soil

WPS (%)	0%	2%	4%	5%	6%	7%	10%
UCS (kN/m^2)	316.4	377.2	389.7	423.0	368.3	354.4	321.0
Percentage increase (%)	-	19.21	23.16	33.69	16.40	12.01	1.45

5.2.1 Effect of Curing On Unconfined Compressive Strength

To study the effect of curing on the unconfined compressive strength, samples made were cured for a period of 3, 5, 7 and 28 days. Fig.6 shows the effect of curing on the strength of the soil. WPS content was varied from 2%, 4%, 5%, 6%, 7% and 10 % by weight of dry soil.

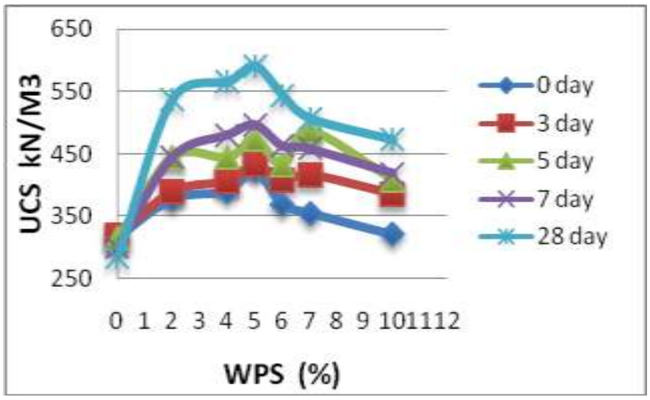

Fig.6 Variation of UCS at Different Curing Days

The results on the effect of varied propositions of WPS are summarized and presented in the Table 5. It was found that the changes in UCS were significant up to 5% of WPS content after 28 days of curing. Further increase in WPS content had no additional increase in the UCS. The percentage increase in the UCS value was approximately 40% at 5% WPS by weight of dry soil.

Table .5 UCS Variations In Moist Curing

Days	**UCS (kN/m^2) with respect to WPS content (%)**						
	0%	2%	4%	5%	6%	7%	10%
0	316.4	377.2	389.7	423	368.3	354.4	321
3	318.3	389.4	406	433.1	408.4	415.9	385.1
5	314	444.9	443.7	473.8	432	486.7	408.5
7	300.6	445.2	480.5	496.9	462.4	458.3	418.4
28	284.2	537.2	565.1	590.8	543.5	507.1	473.1

The soil mixture were prepared at the selected moisture contents and mixed with the Waste Paper Sludge at different percent to determine the percent of additive dose needed to achieve the largest UCS value at 3,5,7 and 28 days of curing period. The 7 days UCS tests of stabilized soils at different WPS and at pre-selected water contents were performed. The improvement in the UCS of the stabilized soil was observed with the increase in the WPS contents. The minimum WPS content was 2% that yield the 7 days UCS of 445.2 as well as the 28 days UCS of 537.2 were observed. The optimum WPS content was 5% that yield the 7 days UCS of 496.9 as well as the 28 days UCS of 590.8 were selected to fulfill the criteria for stabilized subgrade. The addition of stabilizers enhances the strength and stiffness modulus of the raw soils; while at the same time the soil losses its ductile nature or cohesive nature and become more brittle as the axial strain reduced considerably with increase in additive contents. So WPS content after 5%, the unconfined compressive strength reduces considerably.

Table .6 Percentage Increase In Unconfined Compressive Strength Of Soil

WPS (%)		0%	2%	4%	5%	6%	7%	10%
Percentage increase (%) in UCS	**3 day**	-	22.3	27.6	36.1	28.3	30.7	21.0
	5 day	-	41.7	41.3	50.9	37.6	55.0	30.1
	7 day	-	48.1	59.8	65.3	53.8	52.5	39.2
	28 day	-	89.0	98.8	107.9	91.2	78.4	66.5

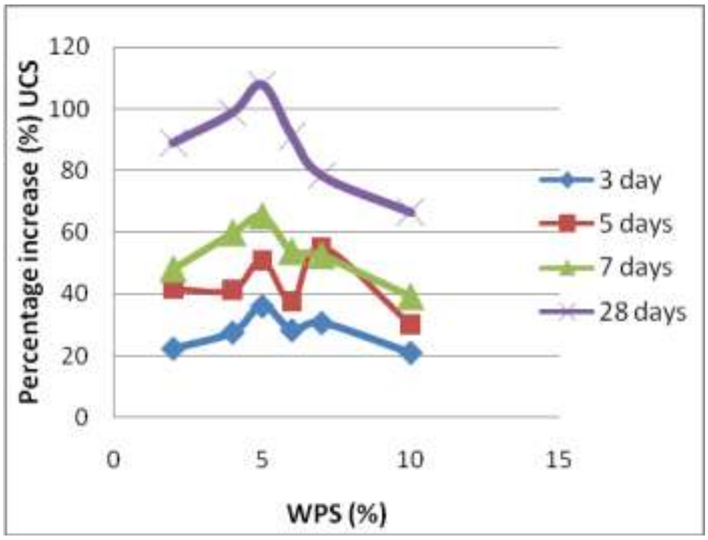

Fig.7 Variation of Percentage Increase In UCS with WPS (%)

In order to know the rate of increase in strength, the unconfined compressive strength of the soil tested after 28 days of curing is taken into account. Fig 7. shows the percentage increase in strength of soil at different days (3,5,7,28) of curing with different contents of WPS.

VI. CONCLUSION

When soil is treated with Waste Paper Sludge an increase in Optimum moisture content and decrease in maximum dry density is observed. It was found that the ratio of decrease in density and increase in optimum moisture content with increase in percentage of additive Waste Paper Sludge. The results from the UCS test for soil for varying proportions such as 2, 4,5,6,7 and 10 percentages WPS increased to better strength. Unconfined compressive strength at 7 days & 28 days gives better results at a dry density of 1.5g/cc and 22% OMC. However the addition of WPS increases strength of soil in a good manner. Curing of specimen showed a better bonding of WPS and clayey soil by absorbing the water content of clay soil by air dried powdered Waste Paper Sludge. WPS becomes a new innovation material that can be used as material for ground improvement. Waste paper sludge can be effectively used with this soft soil for face cut development in tunneling.

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